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(6) A STUDY OF THE IMPACT OF PERSONALITY DIFFERENCES ON TROUBLESHOOTING PERFORMANCE

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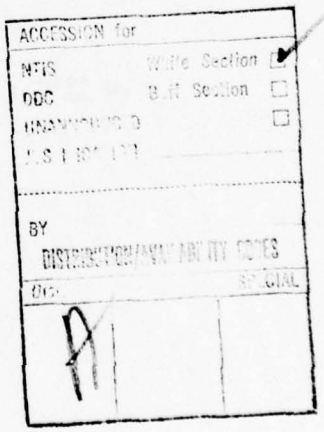

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The purpose of this study was to determine if some maintenance technicians possessed a higher level of native ability for troubleshooting tasks, and, if so, to determine if personality assessment techniques could be used to identify these technicians prior to actual assignment to technical training courses and subsequent career fields. The data used for this study was collected by a previous AFHRL research project which evaluated the performance of electronics maintenance technicians performing troubleshooting tasks using the standard T.O. and two experimental troubleshooting aids (Fully Proceduralized Troubleshooting Aids and Logic Tree Troubleshooting Aids). The authors found that: (1) overall, there was little evidence that some technicians possessed a higher level of native ability than others (experience, however, appeared to be an important factor in determining the extent to which differences in native ability is evident); (2) although average performance improved with experience, differences between the average performances of technicians of different experience levels were not significant; and (3) personality attributes were not consistently related to performance.

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A STUDY OF THE IMPACT OF PERSONALITY DIFFERENCES ON TROUBLESHOOTING PERFORMANCE

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

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Statement of Problem

The Department of Defense spends on the order of $30 billion annually for maintenance, more than half of which is for personnel. Since this expenditure accounts for 20 to 25 percent of the total defense budget, even a small reduction in this area would result in substantial savings (33:1). Much emphasis has been placed on improving maintenance in the equipment area by stressing the importance of reliability and maintainability as design criteria and by developing built-in test equipment. However, little attention has been given to the "people" problem in maintenance.

Research dealing with the "people" problem in maintenance has been primarily concerned with improving the information transfer to the technician on the job. Past and current research projects on maintenance aids indicate that faster and better maintenance can be accomplished if technicians use job performance aids (JPAs) (33:1). The use of JPAs offers the opportunity for reducing training costs by enabling less skilled personnel, and perhaps fewer of them, to carry out maintenance tasks.

Although these research findings are important, they do not completely solve the problem of sustaining maintenance productivity with fewer personnel and at less cost. There exists a further potential for savings through improved personnel selection procedures. The current practice is to assign personnel to schools and subsequent career fields on the basis of aptitude scores (11:3). While aptitude scores are a good indicator of how well an individual will perform in the school, they do not consistently indicate how well he will perform on the job (20). The identification of differential predictors of success other than aptitude scores could lead to expanded training and operating economies through training only those individual possessing the highest potential for performance in a particular type of job.

Justification

With the advent of a volunteer force, rising manpower costs, and tighter defense budgets, military manpower has become one of the most important issues in defense planning and budgeting. Personnel costs increased by 100 percent from 1962 to 1972. In 1962 these costs comprised 42 percent of the total defense budget; in 1972 they were 55 percent of the total defense budget (24:2). The DOD must find methods of increasing the productivity of its personnel in order to offset cuts in both manpower and budget.

In a Rand study conducted in 1972, several recommendations were made for research concerning reduction of personnel costs in the maintenance area (24:10-44). One suggestion was that performance testing should be undertaken for estimating production and the factors influencing it. It was suggested that the proposed study should begin with electronics maintenance since the potential for savings is greatest in this field.

Electronics maintenance is a costly activity. The Defense Science Board estimated that electronics maintenance consumed 25 percent of the DOD FY 1974 operations and maintenance budget, or about $5.6 billion (24:3). Military pay and allowances and other personnel costs for personnel in the electronic maintenance area are about $10,000 per man per year. Training costs are also high. Formal training schools, which consist of an average of 30 weeks, cost approximately $10,000 per graduate. Given an annual turnover rate of 25 percent, the total personnel costs in electronics maintenance is about $12,500 per man per year. The total annual costs of all military personnel in the electronics field is approximately $3.0 billion (24:4).

Past studies have indicated that the use of JPAs for routine maintenance tasks can reduce required training time and make an individual productive almost immediately. The use of JPAs in electronics maintenance could possibly result in savings of $10,000 per trainee. For the entire

DOD, where annual training output in electronics maintenance is approximately 40,000 men, this is a potential savings of $400 million (24:32).

Improving troubleshooting procedures has also been recognized as a method of increasing productivity and reducing costs. Thus, a second recommendation of the Rand study was that an expanded research program with major emphasis on JPAs as a troubleshooting aid should be undertaken. It was suggested that this expanded research should include a study of which troubleshooting aids are the most useful to the technician (24:39). The Rand recommendation specifically identified troubleshooting aids because the development of such aids is inherently more difficult than the development of aids for routine maintenance. Troubleshooting aids must lead the technician from initial symptoms through a series of branching operations to isolate the fault (24:28).

Based on these recommendations, the Air Force Human Resources Laboratory (AFHRL) recently conducted a research project which compared the performance of electronics technicians troubleshooting with three different types of aids. The project evaluated sample groups composed of technicians at three different experience levels. Like the research in other maintenance areas, the AFHRL project concluded that better performance could be achieved by the use of the more proceduralized job performance aid (29:45). Since the use

of JPAs allows the use of less skilled personnel and reduces training time, the AFHRL findings would seem to indicate a great potential for cost reductions. However, the introduction of JPAs does not automatically result in savings (24:19).

While past research has shown the potential for cost reductions in the use of JPAs, actual savings require, among other things, reductions in training and manning levels (24:19). However, training and manning levels can not be reduced at the expense of maintenance productivity. During the AFHRL project, casual observations indicated that the same individuals were the top performers in each sample group regardless of which type of troubleshooting aid was being tested (39). These observations imply that there are individuals who possess a native ability for troubleshooting. Since the problem facing DOD is to maintain or increase productivity with fewer personnel, it would be advantageous to be able to identify individuals possessing the prerequisite abilities prior to selection for training in complex electronics maintenance fields. To identify these individuals, it is necessary to find a variable, or variables, which indicate inherent troubleshooting abilities and can be used as predictors of job performance and productivity. The ability to predict performance would have a great impact on personnel selection and training procedures.

Research Objectives

The objective of this research is to confirm that individuals possessing native abilities for troubleshooting tasks actually exist. Once this confirmation is accomplished, a second objective is to determine whether personality assessment techniques can be used to identify troubleshooting capability potential prior to actual training and career field assignments. A third objective of this research is to confirm the belief that aptitude measures are an accurate indicator of actual troubleshooting performance.

Study Approach

To meet the objective of confirming that individuals possessing inherent abilities for troubleshooting do exist, this research used the data collected on troubleshooting performance during the AFHRL project. The approach taken was to use statistical analysis techniques to determine if the same individuals were the high performers using all three types of troubleshooting aids. This approach was not an attempt to differentiate "good" performance from "bad" performance. Although an individual might attain a higher performance rating with one type of aid than with another, if it could be shown that he is a consistently high performer relative to other troubleshooters, regardless of the type aid used, then it could be inferred that he possesses a higher degree of native ability.

In addition to collecting data on performance, the AFHRL project also administered personality tests to each subject. Once the first objective was achieved, statistical analysis of the performance ratings and personality test scores was conducted to determine if any of the personality traits measured could be related to troubleshooting performance and therefore could be used as predictors of success in troubleshooting tasks. Prior to the analysis of personality test scores, however, it was necessary to determine if there was a significant difference in the performance of the technicians at the three different experience levels since a difference in performance between the three groups would require that the techniques used in the analysis of performance ratings and personality test scores be applied to each group separately.

The third research objective dealt with aptitude measures. The Airman Qualifying Examination (AQE) scores were available for each of the subjects evaluated in the AFHRL project. Statistical analysis of the AQE scores and the performance ratings was performed to determine if a relationship exists between the aptitude measures and troubleshooting performance.

Definition of Terms

Job Performance Aid (JPA)--a type of maintenance aid which is distinguished from other types of maintenance

aids in that it attempts to lay out in logical sequence the tasks that should be performed. It may be fully proceduralized and provide step-by-step directions or it may provide a logical picture of the system to assist the technician in deciding what steps to take (24:29).

Maintenance Aid--stored information, either in devices or documents, available at the job site to assist the technician in performing his task (24:29).

Maintenance Dependency Charts (MDC)--a type of decision aid which helps the technician formulate a strategy for isolating faults. The MDC is a device which helps in understanding the interrelationships of a complex electronics system (24:29).

Troubleshooting--the process of diagnosing, locating, and repairing a malfunction and/or failure in a system or subsystem (7:1).

CHAPTER II

THEORIES AND CONCEPTS

Personality Assessment

Individual differences and their effect on individual behavior has long been recognized. Likewise, man has long been interested in methods of assessing these differences and using this assessment to predict behavior. Early attempts at personality assessment included such methods as astrology, palmistry, and phrenology (21:2). These methods have not survived scientific investigations.

The scientific measurement of personality began only a few decades ago (9:4). It has its roots in the study of individual differences through psychological measurement. This concept was given impetus by Darwin's theory of evolution (21:6). In order to study the effects of human generics, it was first necessary to identify the individual traits which were related to adaptability and survival.

The history of modern personality measurement dates from about World War I (9:5). During this time two different tests were developed. The first was Woodsworth's Personal Data Sheet (21:9). This was a questionnaire type test used to predict the ability of soldiers to adjust to

the strains and stresses of military life. During this same period, Rorschach's "Ink Blot" test was developed, which used an individual's perception of ink blots as an indicator of personality differences (21:10). These methods have been expanded upon and many new methods have been developed in recent years.

Personality Defined

Personality can be defined in many ways. The definition which best fits the purpose of this research is "the nonintellective attitudes that play roles in job selection, classification, and performance [9:16]." This definition describes those attributes which most interest the personnel manager. The personality test is the instrument used to measure these attributes. The objective of a personality test used in this context is to determine whether the person being tested falls in the class of individuals who are most likely to succeed on a particular type of job or who will benefit most from a certain training program (9:18). The test is uniformly applied which gives it some advantages over more subjective methods of personality assessment (3:41). Many personnel managers feel that personality is the most important determinant of success or failure, particularly in jobs requiring the exercise of supervision (36:165).

Personality Tests

The term "personality test" may refer to a variety of psychological measuring instruments (17:23). The two most often used personality measuring devices are paper-and-pencil inventories and projective techniques (36:165).

Paper-and-pencil inventories are composed of a series of questions or statements. There are no right or wrong answers. The person taking the test is asked to tell how he feels or would react in a given situation (40:189). He may be asked to respond by answering "yes" or "no" or "sometimes," "always," or "never;" or he may be given a multiple list of answers from which to choose (36:165). The responses are scored for particular traits or attributes. The responses which are being scored have usually been identified by statistical analysis or by subjective means as being responses that are characteristic of that trait or attribute (40:190).

The projective techniques test confronts the subject with several items such as ink blots or pictures. It must be administered individually rather than in groups. The subject is encouraged to respond freely, telling what he sees in the blot or making up a story about a picture. His responses are presumed to be projections of his thoughts, wishes, desires, and needs (36:166). A trained test administrator interprets the responses and makes an

assessment of the subject, which is usually in qualitative rather than quantitative terms (40:190).

Personality type tests can be structured to measure different facets of personality. Different types of personality tests can be grouped according to the particular attribute that they are attempting to measure. These major groupings are interest, preference, behavior, and attitude (17:22).

Interest tests, as the name implies, are designed to indicate things the subject might be interested in. This type personality test is one of the most familiar. The test consists of a variety of items, each of which calls for a response indicating the subject's interest in the activity or subject specified by that item (17:22).

Preference tests are characterized by the format in which they are presented. The test items consist of things which a person might say about himself or about others. The subject indicates his preference by choosing the response which most closely describes his feelings (17:22).

Behavioral tests are composed of items which are statements of specific observable behavior, such as "going to a movie [17:23]." This test is based on the assumption that what a person actually does is a more accurate measurement of personality than what his interests or preferences are.

The most distinct of the personality tests is the attitude measurement inventory. The attitude statements used in this test are stimulus elements to which the subject responds in terms of his likes, dislikes, interest, feelings, etc., just as he does in other types of tests. The test is usually made up of a series of items that refer to some specific organization such as the church or a social group, or to specific issues, social institutions or any other subjects which can be defined (17:24).

Another application of attitude tests is the evaluation of one individual by another. This form of the test would consist of items that describe the performance of an employee on the job or other activity (17:24). In this form, the test would be an attitude questionnaire used by a supervisor to indicate his attitude towards a subordinate's performance.

For any test of individual differences to be effective it must have adequate measurements. There are many factors which determine the adequacy of the measurements; however, a measurement can generally be described as adequate if it meets three criteria (9:250).

The first criterion is that the responses from which the indices of measurement are obtained must be determined as completely as possible by one important personality attribute (9:250). In other words, there must be a direct relationship between the subject's response to a

particular item and some characteristic of his personality. This criterion is simply asking whether the test is measuring some important attribute well.

A second criterion is closely related to the first. Besides being able to adequately measure a particular attribute, the test items must indicate the degree of the attribute characterizing the subject at that period of his life (9:251). This criterion concerns measuring a trait rather than the state in which the subject happens to be. The state indicates how the subject feels under particular conditions. The personality test is concerned more with measuring underlying determinants of behavior. Trait measurements are an average over most situations, or a generalization of how a subject usually feels (9:180). Economy and convenience require that the measurement be administered at one point in time. However, if this criterion is met, a measurement index will be obtained which will closely approximate the mean index obtained by administering the test a number of times. To meet this criterion, the setting, the task, and the test items must have a clear psychological meaning for the subject. When these elements of the testing environment have sufficiently strong impact, they determine the subject's responses (9:251). Influences from temporary states or other variables are elminated.

The third criterion is that the indices of measurement must differentiate dependably among subjects (9:251). The purpose of the personality test is to measure differences among subjects or particular traits. It is assumed that such differences exist. The procedures used to measure this difference must produce a range of scores over different subjects.

The personality test is constructed to validly measure some individual trait difference. These three criteria overlap to some extent in that they are all related to that objective. But taken separately, they each indicate a particular area which might affect the validity of the test.

Test Validity

The most important question to be asked about a psychological test of any kind concerns its validity. Validity is the degree to which the test actually measures what it is supposed to measure (1:107). Since there are different tests attempting to measure different personality attributes, there are different methods of validation. A method which would be appropriate for demonstrating the validity of one test would not necessarily be appropriate for another (21:128). There are some general methods of validation which are recognized as being appropriate. Each method applies to particular objectives for a test (40:128).

Content validity is evaluated by showing how well the content of the test samples the subject matter or kinds of situations that the test is supposed to measure (40:128). This type of validity is not based on criteria. No attempt is made to gather data or information to form a statistical basis for prediction. This method is based on the judgement of experts in a particular field (3:43). Although content validity applies particularly to achievement and aptitude tests, personality tests also require its use to some extent (21:128). For example, a test designed to measure leadership qualities might be composed of items which require responses that would indicate the subject's behavior in situations requiring leadership abilities. If these test situations are representative of leadership situations in general, then the test can be said to display a content validity (21:129).

A problem in using the content validity method is the possibility that the test is based on "face validity" (3:43). That is, the contents appear to be meaningful but are not truly significant. This is particularly an argument against paper-and-pencil personality tests (21:129). Therefore, content validity, although an important requirement, is not sufficient in itself for determining the usefulness of a test. Other methods of validity determination also must be used (3:48).

Personality assessment is most often concerned with predictive validity (21:130). Predictive validity is evaluated by showing how well predictions made by the test are confirmed at some future time (40:128). It is not necessarily concerned with predicting the future but rather with predicting relationships (5:96-97). Predictive validity refers to "the accuracy with which we can make guesses about one characteristic of an individual from another characteristic [14:338]." The test measure is called the predictor and the characteristic being guessed at is called the criterion. The predictive validity is determined by a numerical index. This index is given by a correlation between the predictor and the criterion (21:130).

Another validity measurement is concurrent validity. Concurrent validity is evaluated by showing how much the scores on a test are related to some present criterion of performance or status (40:128). Rather than establishing a correlation between present test data and criterion data available at some later time (as in predictive validity), concurrent validity establishes a correlation between test data and concurrently available criterion data (23:77). The object is to take some known criterion, such as job performance, and relate it to some test score.

Caution must be used in determining the validity of a test with concurrent information. A high correlation may mean that experience is being tested rather than the

desired characteristic (3:43). When this happens, the experience factor is known as a contaminant. Such contamination results when the influence of any extraneous factors are reflected in the measurement (36:102). Statistical means should be used to remove any such contaminants from the tests (3:43).

The last of the general methods of determining validity is construct validity. A construct can be defined as the trait which the test is attempting to measure (23:90). Construct validity is evaluated by determining what trait or attributes a test measures (40:128). This method is sometimes used when a test lacks appropriate criteria against which it can be evaluated (3:44). Frequently, construct validity is determined by correlating one test with another which has previously been used to measure the same attribute. Another method would be to use factor analysis, a statistical process which can identify the extent to which various tests measure the same attribute (40:128).

Any of these methods of determining validity could be used for different personality type tests. However, in keeping with the earlier definition of personality, the two most often used methods would be predictive and concurrent validity. In both of these concepts of validity, a criterion of job performance is usually involved (40:128).

Test Reliability

The reliability of a test is also important in determining its usefulness. As used in the measurement of individual difference, reliability means consistency (1:67). The reliability of a test is the degree to which the test measures consistently the attribute it is supposed to measure (40:129). There are several methods of determining test reliability.

The test-retest method determines the reliability of a test over time. A reliable test is one in which an individual will obtain about the same score on successive testings (36:141). Retest reliability is probably the most realistic and useful method from a practical point of view (17:41). However, if memory or practice from the first test can affect scores on subsequent tests, this method should not be used (40:129).

A second method of determining test reliability is comparable form or alternate-forms reliability. This method uses two or more different tests that are supposed to measure the same attribute (17:39). A correlation is then established between the scores obtained on each of these tests to determine the degree of reliability (40:129).

A common criticism of both the test-retest and comparable forms method is that they require two separate testing sessions. A third method of determining reliability, the split-halves method, requires only a single

test administration. The total test is divided into halves. Each half of the test is a miniature representative of the entire test (36:143). Each half is scored separately and these two scores are then correlated to determine test reliability (40:129).

Test reliability and validity must be considered together. A test may have high reliability and still be worthless in certain situations (40:130). However, reliability is important because it limits validity (9:171). Theoretically, a test's maximum potential validity is given by the square root of its reliability. For example, if a test's reliability coefficient is determined to be 0.36, its validity coefficient can not exceed 0.60 (36:146).

Since maximum validity is determined by reliability, the choice of tests to be used depends upon the coefficient of validity required. This requirement is determined by what use is to be made of the test. Personality tests are usually used for one of two objectives: to make an analysis of each individual subject tested or to select from a large group of subjects those who will surpass the rest in some respect. It is this latter use that concerns choosing individuals who are most likely to succeed at a particular job. This use is most appropriate to the earlier definition of personality and the objective of personality testing. For this purpose, the validity of a test can be relatively low and still be valuable (40:131).

Criticisms and Limitations

Two Congressional hearings were held in 1965 to review personality assessment practices. Although the primary purpose of the hearings was to investigate the use of personality tests in federal government personnel selection procedures, many more aspects were also investigated. The criticism of personality test falls into two problem areas: problems of usage and problems involving moral issues (21:203).

Usage problems involve test misuse and test invalidity. Test misuse is the invalid use of an assessment procedure that has legitimate uses. Test invalidity involves the use of an assessment procedure whose validity has not been established for any purpose (21:203). Test misuse is probably the most serious problem in personality testing, especially in personnel selection procedures (36:177).

A moral issue problem concerns confidentiality. In some instances, individuals are concerned that the information gained from personality tests might be used against them in some way (21:204). Another moral issue concerns the individuals' right to privacy. Personality tests are said to invade personal privacy (17:16).

An important limitation of personality tests is that they tend to be transparent. The subject can often determine by reading the items which response will most favorably portray his personality (36:183). Again, this

problem is especially pertinent to personnel selection procedures.

Applications in Personnel Selection

Psychological testing has been an important facet in personnel selection for industrial personnel. Throughout the 1950s much emphasis was placed on selection criteria established by psychological tests (38:282). Psychological tests when used properly can reduce turnover and increase effectiveness of the selected work force (26:170). The Civil Rights Act of 1964 has caused industry to place less emphasis on psychological tests.

In industry the most frequently used method for assessing personality is the self-report questionnaire. The Minnesota Multiphasic Personality Inventory, the Eysenck Personality Inventory, the Cattell 16 Personality Factor Questionnaire, the Guildford-Zimmerman Temperament Survey, and the Gordon Personal Profile and Personal Inventory are the ones most often used by industry (22:6). Other approaches to the assessment of personality, such as the Rorschach ink-blot test, are usually more time-consuming and require full psychological training for their use and interpretation.

The Minnesota Multiphasic Personality Inventory (MMPI) has been the most frequently used personality inventory (8:243). Hospitals have used the MMPI with

biographical data to select successful hospital aids (4:562).

Another personality measure frequently used by industry is the Eysenck Personality Inventory. The Eysenck Personality Inventory consists of 48 items. This test measures two main traits: neuroticism and extroversion. Neuroticism refers to general emotional instability. Neurotic breakdown under stress can be predicted with this measure. Extroversion refers to uninhibited, outgoing, and sociable characteristics a subject possesses. Business has used this measure as a predictor of success of sales personnel (19:201).

The Cattell 16 Personality Factor Questionnaire and the Guildford-Zimmerman Temperament Survey are similar personality surveys. These two tests predict general activity, restraint, ascendance, sociability, emotional stability, objectivity, friendliness, thoughtfulness, personal relations, and masculinity. Reliability and validity of the two tests are highly established within industry and business (19:197-98). The Cattell 16 Personality Factor Questionnaire and the Guildford-Zimmerman Temperament Survey have been found to be most valid and useful to assess traits in normal people for industry, business, and school (19:197-98).

The Gordon Personal Inventory and Personal Profile have been found to be useful in industrial selection,

appraisal, vocational guidance, personal counseling, classroom demonstration, and basic research (15:15; 16:15). In industrial selection the Gordon Personal Inventory and Personal Profile has achieved wide usage. Its main appeals are its brevity, its relative resistance to distortion, its acceptability to the applicant, and most important, its ability to predict success in many jobs. The eight traits measured by the two Gordon inventories are cautiousness, original thinking, personal relations, vigor, ascendancy, responsibility, emotional stability, and sociability. The Gordon Tests have repeatedly demonstrated their usefulness in selecting candidates for a particular job (15:15; 16:15).

Industry and business have used the Rorschach inkblot test to a lesser extent, because of its questionnable reliability and validity. The Rorschach test is used to assess level of intelligence, creative potential, spontaneity, degree of mood fluctuation, depression, euphoria, and the extent of anxiety (19:276). Some success was shown in differentiating the outstanding from ordinary or unsatisfactory mechanical workers on the basis of their Rorschach responses (6:21).

Psychological testing has not been prohibited by the Civil Rights Act of 1964. The Act prohibited discrimination in hiring, and only tests that are discriminatory in nature are prohibited (38:283). To meet the requirements of the Supreme Court and at the same time

satisfy the needs of industry and business, a simple rule can be applied: people with an equal probability of success should have an equal probability of being hired (3:174).

Review of DOD Research

The DOD faces the same problems as business and industry in personnel selection. Although many studies have been conducted concerning personnel selection techniques used by the DOD, few have been directed toward personality assessment. What follows is a review of some of the most recent uses of personality testing in the DOD.

U.S. Army Study. The United States Army Personnel Research Office conducted a validation of a experimental electronics selections battery. One of the objectives of their research was to develop a measure for improving assignment of personnel to electronic jobs. A 425-item inventory measure was used by the Army Personnel Research Office to measure such behavioral aspects as conscientiousness, persistence, stability, attitudes toward schooling, work, authority, and information regarding background, activities, and interests. Results of the Army's validation effort concluded that behavioral aspects could be used as predictors of success in the electronics-electrical career field both at high complexity and low complexity levels (2:14-18).

Philco Study. In 1967 the Philco Corporation completed a DOD study which attempted to quantify the personal variables which are necessary to good performance in maintenance (6:3). The project studied Air Force subjects at the Cheyenne Mountain Complex near Colorado Springs, Colorado. The objective of their research effort was to investigate the personnel element in the maintenance environment and its influence on downtime. One of the comments in the report stated that little work has been done in attempting to identify the variables associated with human performance in maintenance of military electronic subsystems (6:13). Philco, in its research effort, used three well established personality inventories to quantify certain traits. Tests used by Philco were the Minnesota Multiphasic Personality Inventory, Survey of Interpersonal Values, and the Strong Vocational Interest Blank. Through the use of these test scores, certain personality variables were investigated. Although the conclusions by Philco Corporation are somewhat vague, the report did state that certain of the personality variables did show promise of having predictive capability of human performance in electronic systems maintenance (6:8).

Pilot Selection. Application of personality testing in other military career fields has proven successful. The United States Army has found such personality constructs

as self-confidence, activity level, and distractibility and indecisiveness to be good predictors of success of pilots in helicopter training school (6:21).

U.S. Navy Study. A recently completed test conducted by the Naval Medical Research Institute studied certain personality variables and their relationship to task performance (18:731). Personality was measured by the Insolence Scale. The Insolence Scale was developed to measure 27 self-description items. Affirmative answers to the Insolence Scale conveyed the impression of a physically active, aggressive, somewhat hostile and reckless personality, who early in life became independent of family and grade school control, and who, it is suspected, continues to maintain an independent and rebellious attitude toward most attempts at controlling his behavior. Subjects with high Insolence Scale scores displayed lack of interest in the jobs they performed for this experiment. In recent field application the results parallel those observed in the lab setting (18:742).

An extensive literature review uncovered only a few cases where the DOD has used personality variables as one of the selection criteria for career assignments. Aptitude alone has remained the primary criterion for assigning personnel to career fields (20; 39).

Maintenance Aid Research

Over the past ten years DOD has placed much emphasis on improving equipment as an approach to better maintenance. However, little attention has been given to the area of maintenance information. No major changes have been made to the conventional technical manual systems. Although some gradual improvement has occurred, there has been no innovative effort to improve the "people" part of the maintenance problem (7:1; 33:8). There have been a number of small-scale experiments and demonstrations of new ways of presenting information that enable technicians to perform faster and more accurately with less training. However, the reactions to the results of these experiments have not been overwhelming.

> Although some of these techniques appear to have the potential for greatly reducing cost of maintenance perhaps by 30% or more and improving equipment availability, there has been relatively little application of these research results outside of the laboratory [33:8].

The research has been primarily concerned with performance aids (33:8). These devices contain guidance information that helps the technician perform a particular job at hand and are "people" rather than equipment oriented. The aid may be a very specific step-by-step set of directions that require no decisions to be made or it may be something that gives a more general picture of the system and helps the technician decide what to do next. The

majority of past research has focused on various specific or fully proceduralized aids for non-troubleshooting tasks (33:9).

The objective of past research has been to provide simple, complete, and current information to the technician without the need for cross-referencing and retention (33:9). Fully proceduralized performance aids break up the task into easily understood steps and present unambiguous directions using simple language and relevant illustrations. Well designed aids are based on a careful analysis of the task and take into consideration the amount of training and experience of the personnel who will be using them. In contrast, current maintenance documentation rarely considers training and experience. Instead, it is often written before the equipment is actually produced and is not based on the tasks required to repair the equipment (33:9). The problems caused by this process were revealed in an analysis of the maintenance actions required for the doppler radar system of the C-141. It was found that the isolation and repair of one malfunction required reference to 165 pages of 8 different documents. If no mistakes were made, 41 changes in document location were required (33:10).

Fully proceduralized aids have been developed for troubleshooting tasks, but most of the research on troubleshooting has involved decision aids (24:29). These aids

help the technician understand the system and formulate a strategy for isolating the fault. Most of the decision aids have included variations of the Maintenance Dependency Chart (MDC), which can vary greatly in complexity and which indicates what elements are interrelated (24:29). Past research projects concerning maintenance aids have been summarized a number of times (6:11-30; 10:3-17; 32:8-19). What follows is a review of those projects most closely related to this research effort.

FORECAST

Project FORECAST has been concerned primarily with the training demands posed by new weapons systems. The objective of the research was to develop and test methods for analyzing an electronic weapon system to define a set of skills and the knowledge necessary for operating and maintaining the system (34:43). The aids produced are decision type aids such as troubleshooting block diagrams, waveform guides, and blocked schematics. Such aids are used during training to convey system understanding and to teach troubleshooting (33:15).

In 1958, an experimental 12-week FORECAST training program was conducted for Army M-33 antiaircraft fire control system electronic technicians (34:43). A comparison of performance was made between 20 experimental subjects for the 12-week program and 17 subjects from the normal

30-week course. The experiment used 89 troubleshooting tasks administered over a 9-day period. The mean test scores and standard deviations show very little difference in the performance of the two groups (34:43-46). The important difference was the length of training. The group which received the shortened 12-week course performed as well as the group which received the standard 30-week course.

Another test was conducted in 1963 with 98 subjects using Navy Loran equipment. Twelve subjects had conventional training and manuals. The remaining number had FORECAST training and manuals. The FORECAST subjects identified an average of three times as many malfunctions as the conventional subjects (33:16).

JOBTRAIN

JOBTRAIN was the result of research by the Human Resources Research Organization (HumRRO). The study was designed to develop and evaluate methods for producing a combination of training and job aids for maintenance of electronic communication equipment such that less training time would be required than under the standard course and manuals (13:3). The aid and training course was compared with standard documents and training in 1962 at Fort Gordon, Georgia. The subjects were radio relay and carrier repair technicians. The control group consisted of

19 trainees who had attended the normal 25-week school and used conventional documents. The experimental group consisted of 21 trainees who had received the 11-week JOBTRAIN course and used the JOBTRAIN aid. The two groups were given 18 problems to troubleshoot (13:20-29). The test results indicated that the two groups performed equally well since no statistically significant differences were found. It was concluded that the JOBTRAIN training and aids were as effective as traditional training and manuals and that a 50 percent reduction in training time could result from the JOBTRAIN approach (33:17).

MAINTRAIN

MAINTRAIN, another HumRRO project, was an effort to develop an improved manual for use in troubleshooting complex electronic equipment. The manual was tested by having recent missile school graduates troubleshoot 44 faults with Nike Ajax Missiles. The subjects were matched on the basis of Air Defense School grades and divided into two groups of eight. One group used conventional manuals and the other used the MAINTRAIN manual. The group using the MAINTRAIN manual located 42 percent more malfunctions in 41 percent less time (33:17).

SIMS

Symbolic Integrated Maintenance System (SIMS) is a program which also deals with maintenance manuals. A

military specification was written to set forth requirements for this type of technical manual for the maintenance and repair of electronic systems and training of military personnel (35:79). In research conducted in 1964, SIMS manuals were constructed for a Coast Guard radar set. An experiment using 42 subjects divided into two groups showed that the group using the SIMS manuals identified the three test malfunctions 96 percent of the time. The group using conventional manuals had only a 70 percent success rate. Additionally, the SIMS group took only half as much time to troubleshoot (35:80-85).

PIMO

Project PIMO (Presentation of Information for Maintenance and Operations) has been the most extensive effort in the job aid area (27:9). PIMO consists of fully proceduralized aids for non-troubleshooting maintenance tasks and simplified maintenance dependency charts for troubleshooting. The aids used a fixed format and a preferred verb list with a limited number of steps per page. Between August 1968 and April 1969, a test was conducted at Charleston AFB, South Carolina, to determine the effectiveness of PIMO. Experienced and inexperienced technicians performed maintenance on C-141A aircraft using PIMO job guidance presented in audio visual and booklet modes (27: 9-10). Performance was measured in terms of time to

perform tasks and procedural errors. The performance was compared with the performance on the same jobs by experienced technicians performing in the normal manner. Several conclusions were drawn from the test results. First, both experienced and inexperienced technicians showed strong evidence of learning while performing with the PIMO Job Guides. Generally their performance times reduced (after 7 or 8 trials) to approximately the same level as the very experienced technician performing under "normal" conditions. During the learning period, all performance was error-free (27:13). This is not the case when technicians perform in their regular fashion. Secondly, inexperienced technicians performed as well as experienced technicians when both used PIMO non-troubleshooting aids. During the experiment, the users expressed an overwhelmingly positive reaction to PIMO.

Only experienced personnel were used in testing the PIMO troubleshooting aids. There was an 11 percent reduction in time using PIMO as opposed to standard procedures. Forty troubleshooting actions were performed with PIMO with one error while forty-one actions were performed using standard procedures with 12 errors (27:19).

Naval Air Systems Command Project

In 1970 a field test of fully proceduralized non-troubleshooting aids was conducted for the Naval Air

Systems Command onboard the USS Saratoga and at the Naval Air Station, Oceana. The test involved 19 organizational maintenance tasks on the F-4J (28:6). Fifty-two technicians performed a total of 635 maintenance actions. Portions of the existing Maintenance Information Manuals that were relevant to the malfunctions used in the test were collected, checked for accuracy, and packaged for each maintenance task so that the content of the traditional material would be as available as the job guides. During the test, the experienced personnel had the option of using or not using the exerpts from the manuals. The inexperienced personnel were required to use them (33:26). Using quality assurance standards as a guide, experienced and inexperienced personnel using standard procedures performed satisfactorily 74 and 63 percent of the time, respectively. When using the job aids, experienced and inexperienced personnel performed satisfactorily 100 and 94 percent of the time, respectively. These results showed that inexperienced personnel performing with job aids were 20 percent better than experienced personnel using standard procedures (33:26).

AFHRL Project

The Air Force Human Resources Laboratory (AFHRL) at Wright-Patterson AFB, Ohio, recently completed a field test on job aids (29:3). The test involved three different

aids: Logic Tree Troubleshooting Aids (LTTA), Fully Proceduralized Troubleshooting Aids (FPTA), and the standard Air Force Technical Order (T.O.). The most significant difference between the types of aids is the degree of proceduralization (29:4). The FPTAs contain the highest degree of proceduralization and T.O.s the lowest, with the LTTAs somewhere in between the two.

The standard Air Force T.O. contains much of the information needed to successfully troubleshoot the equipment. However, the technician must decide what data he will use and how and when it will be used. The manuals are prepared assuming that the technician has experience and training in the use of test equipment, in locating most parts within the equipment, and interpreting schematic diagrams (29:5).

The LTTAs are more proceduralized than conventional T.O.s. Specific instructions are provided both in the checkout procedure and in the troubleshooting procedure. The troubleshooting logic trees give exact procedures to be performed and ask questions about results obtained while monitoring voltages, waveforms, and/or resistances at specific points in the circuit (29:6). The yes or no answer to these questions provides the logic in the fault isolation procedure. Each logic path ends with instructions to replace a faulty component. Sometimes a path will first identify the faulty stage or assembly and will

direct the technician to perform the checkout procedure for that stage or assembly.

LTTAs are similar to standard T.O.s in that they are prepared for the most experienced technician. The technicians are assumed to be able to properly choose and use test equipment, locate most parts and test points, and read and interpret functional block diagrams (29:6).

FPTAs provide complete step-by-step instructions for both checkout and troubleshooting tasks. They are designed for use by both experienced and inexperienced technicians. All specific test equipment and tools are called out in each section as they are required. Each prime hardware item and the more complex test equipment mentioned in the aid are accompanied by a call-out number which is keyed to an illustration of the items appearing on that same page or a facing page (29:8). For test equipment, the illustrations appear in a fold-out page at the back of each section. The FPTAs are complemented by maintenance support information manuals. These manuals contain instructions on test equipment operation, special testing procedures, and wiring diagrams. They are not required for use with the FPTAs but are available if needed. To facilitate use of the aids by experienced personnel, the basic checks, expected readings, and tolerances are underlined. Underlined information permits the experienced

technician to rapidly scan the test and focus his attention on important data only (29:8).

A carefully controlled experiment was conducted under field conditions to assess the merits of T.O.s, LTTAs, and FPTAs in locating and correcting problems in two electronic subsystems of the C-141A aircraft. For the purposes of the test, three experience levels of Air Force technicians were sampled; recent technical school graduates, field-experienced technicians with six months or less experience, and technicians with more than six months experience. Since the technical school graduates were not normally expected to be able to perform with T.O.s, they were not measured with this aid. For this reason the test was conducted with Keesler technical school graduates as a separate analysis (29:10).

The results of the AFHRL study are as follows (29:45):

1. The quality of performance was not affected by the use of FPTA or LTTA for different experience levels. Low experience level subjects who used the T.O. had lower performance ratings.

2. Total number of problems solved were greater using the FPTA and LTTA as compared with number of problems solved using the standard T.O.

3. Problems were solved with more consistency with either the LTTA or FPTA.

4. Spare parts consumption was significantly lower with the LTTA or FPTA.

5. The T.O. was viewed as a much more difficult aid to use as compared to the FPTA and LTTA.

6. At all levels of complexity of troubleshooting examined, the T.O. was rejected in favor of either the FPTA or LTTA. The FPTA was the most favored by the subjects.

Implications for Research

The little research that has been conducted concerning the maintenance "people" problem has dealt with maintenance aids in an attempt to improve the information transfer to the technician on the job. Improved maintenance aids have been shown to have potential for cost reductions in personnel areas.

The maintenance aid research, while very important, does not approach the problem of personnel selection and classification. An extensive literature review has revealed very little work done in an attempt to improve personnel selection and classification procedures within the DOD. The literature review did show that personality testing is one method which has been commonly used for personnel selection in business and industry.

Personality testing, although somewhat limited by the Civil Rights Act of 1964, can be an effective tool in

predicting job success (12:217). The implication is that if certain personality traits could be identified as predictors of success in maintenance jobs, the quality of the maintenance work force could be improved through improved selection procedures. The combination of improved selection procedures and improved maintenance aids would have a great potential for savings in maintenance costs.

Research Propositions and Hypotheses

The following is a listing of the propositions and associated hypotheses which are derived from the literature review and the research objectives.

Proposition 1: Individuals who perform well using one type of troubleshooting aid, tend to perform well using the other types of troubleshooting aids.

Hypothesis No. 1: For technicians with no experience, using the FPTA and the LTTA, there are differences among the mean ranks of the subjects' performance.

Hypothesis No. 2: For technicians with six months or less experience, using the FPTA, LTTA, and the T.O., there are differences among the mean ranks of the subjects' performance.

Hypothesis No. 3: For technicians with more than six months experience, using the FPTA, LTTA, and the T.O., there are differences among the mean ranks of the subjects' performance.

Proposition 2: A significant difference exists between the troubleshooting performance of technicians of different experience levels.

Hypothesis No. 4: There is a difference in the troubleshooting performance of technicians with no experience, six months or less experience, and more than six months experience.

Proposition 3: A relationship exists between specific personality traits and demonstrated troubleshooting ability.

Hypothesis No. 5: A relationship exists between Ascendancy and demonstrated troubleshooting ability.

Hypothesis No. 6: A relationship exists between Responsibility and demonstrated troubleshooting ability.

Hypothesis No. 7: A relationship exists between Emotional Stability and demonstrated troubleshooting ability.

Hypothesis No. 8: A relationship exists between Sociability and demonstrated troubleshooting ability.

Hypothesis No. 9: A relationship exists between Cautiousness and demonstrated troubleshooting ability.

Hypothesis No. 10: A relationship exists between Original Thinking and demonstrated troubleshooting ability.

Hypothesis No. 11. A relationship exists between Personal Relations and demonstrated troubleshooting ability.

Hypothesis No. 12: A relationship exists between Vigor and demonstrated troubleshooting ability.

Proposition 4: There is a positive relationship between AQE aptitude measurement scores and demonstrated troubleshooting ability.

Hypothesis No. 13: There is a positive relationship between Mechanical aptitude, as measured by the AQE, and demonstrated troubleshooting ability.

Hypothesis No. 14: There is a positive relationship between Administrative aptitude, as measured by the AQE, and demonstrated troubleshooting ability.

Hypothesis No. 15: There is a positive relationship between Electronics aptitude, as measured by the AQE, and demonstrated troubleshooting ability.

Hypothesis No. 16: There is a positive relationship between General aptitude, as measured by the AQE, and demonstrated troubleshooting ability.

CHAPTER III

METHODOLOGY

This research used the data which was collected during the previously described AFHRL research project (29; 30). The first section of this chapter describes the population and sample for which data was collected. The remainder of the chapter describes the data collection procedures and the statistical analysis techniques for each of the research propositions.

Description of the Population and Sample

The population for the AFHRL project consisted of Air Force enlisted personnel in the 328X4 Air Force Speciality Code (AFSC) (Avionics Inertial and Radar Navigational Systems Specialists). A sample of 54 personnel in this AFSC was studied (30:16). This total of 54 was divided into three subject groups based on experience level. The first group consisted of 18 3-level airmen who were recent graduates of the Keesler Technical Training Center (KTTC) Course 3ABR32834. These subjects were first-term enlisted airmen who had completed basic training and who went directly into technical training at KTTC. They had no field experience. The airmen were retained at

Keesler for a two-week period beyond course graduation and entered as subjects for the experiment (30:14).

Graduation dates and sizes of the classes used were: 7 October, 7 graduates; 21 October, 9 graduates; 4 November, 9 graduates. Each graduate was assigned to an initial evaluation group by means of a random selection process (30:19). All graduating classes were used in total, providing 25 subjects on which complete data was collected. Since the experiment required a sample size of only 18 subjects, the decision was made to drop the 7 October class from the analysis (30:29). The decision to drop the first class was based on the fact that no "dry-runs" had been conducted with the test equipment prior to evaluating the first subjects; therefore, any unusual equipment problems or experimental bias would have been more likely during the evaluation of the first group (31). The two classes used in the analysis were believed to be a representative sample. Since all assignments to the KTTC course were based on the same selection procedures and criteria, there was no reason to believe that any particular class differed significantly from any other class.

The two remaining subject groups were obtained from Air Force enlisted personnel in the 328X4 AFSC assigned to operational units of the Military Airlift Command (MAC) and performing maintenance on the AN/ASN-35 (computer) and AN/APN-147 (radar) systems in C-141A

aircraft (30:15). Each group consisted of 18 subjects and were classified according to length of experience. One group of 18 were airmen who had either been awarded the 5-level of the AFSC within the last six months or for whom award was imminent (30:16). This group had six months or less experience on the system. The remaining 18 subjects were 5-level airmen with more than six months experience. Three MAC bases were visited to obtain the required number of subjects for these two groups.

The choice of bases to be visited to collect data was limited by two considerations (31). First, the experiment was confined to MAC bases within the continental United States. Secondly, certain U.S. bases (Charleston AFB, Norton AFB, and Altus AFB) were not considered since studies concerning maintenance aids had already been conducted at these locations and the results of any additional experiments might have been contaminated. Within these limitations, an attempt was made to obtain the widest possible range of geographical locations. The bases chosen were: McChord AFB, Washington; Travis AFB, California; and McGuire AFB, New Jersey (20:17).

Each of the three bases provided a list of personnel with the appropriate AFSC and experience level. The subjects for the experiment were randomly selected from these lists (31). Due to the nature of Air Force assignment policies and procedures, it was believed that all

elements of the population of interest were as likely to be assigned to any of the three bases visited as any other base; therefore, the sample was believed to be representative. Since the actual experiment resulted in a wide range of performance, there was no reason to believe that the sample was not representative (31).

A sample size of 18 subjects was decided upon for two basic reasons (31). First, it was decided to design the experiment around a small sample because of the cost and time involved in collecting the data. Secondly, the specific number of 18 was chosen to balance the experimental design. Since there were two types of aids to be evaluated in one group and three types in the other two groups, a sample of 18 allowed an equal number of subjects to be evaluated with each type of aid in all three groups.

Research Proposition No. 1

Testing Environment

An Air Force trailer configured to include AN/ASN-35 and AN/APN-147 bench mock-ups and a mock-up of the C-141A cockpit was taken to four separate Air Force bases: Keesler AFB, Mississippi; McChord AFB, Washington; Travis AFB, California; and McGuire AFB, New Jersey (20:17). The trailer served as the experimental setting for the controlled evaluation.

Since it was difficult to obtain access to C-141 aircraft for use with the tests, the mock-up of the C-141 cockpit and avionics equipment bays was developed and installed in the test trailer (30: 17). The cockpit mock-up provided a means of simulating the troubleshooting tasks without requiring access to an aircraft. It consisted of mock-ups of all instrument panels in the cockpit. All AN/APN-147 and AN/ASN-35 components were "live" and functioned in the same manner as the actual cockpit (30:17). All other components on the instrument panels were represented by photographs.

Technical Accuracy of Troubleshooting Test Problems

The equipment problems against which each of the three types of troubleshooting aids were evaluated were selected after an extensive review of worldwide maintenance actions on the AN/APN-147 and AN/ASN-35 systems for calendar year 1974. The source of the maintenance action data was Air Force Logistics Command reports RCS: LOG-MMO (AR) 7167 and LOG-MMO (AR) 7168 (30:13). The data contained in these reports were summarized to provide identification of maintenance areas which appeared to be logical and representative selections for development of troubleshooting test problems. In order to provide field verification of the validity of the data summarizations, the results were discussed in detail with maintenance personnel at

Charleston AFB, South Carolina (30:13). These discussions revealed detailed information, not available in the AFLC reports, concerning specific parts or components which were contributing most of the maintenance problems of the systems under study. This information was considered in selecting the troubleshooting test problems. A total of 30 malfunctions were selected and located on an appropriate system schematic to verify that the problems selected were satisfactorily distributed throughout the system. Fifteen of these malfunctions were then selected for incorporation into the experimental design.

Testing Procedures

Keesler Subjects. These airmen were available on a full-time basis for two weeks following graduation from Course 3ABR32834. Each subject was assigned to an initial evaluation group by means of a random selection process (30:19). The subjects were given remedial training courses to familiarize them with the 13 items of test equipment to be used for performing troubleshooting procedures in the evaluation.

A total of 15 equipment faults were selected as test problems in the troubleshooting evaluation. However, since a decision had been made not to test the Keesler subjects using technical orders, one of the 15 problems was eliminated. Thus, the number of problems was balanced

so that an equal number could be evaluated with each of the two troubleshooting aids: seven with the LTTA and seven with the FPTA (30:20). Each equipment fault was isolated an equal number of times with both LTTA and FPTA documentation. The type of troubleshooting aid used first by the subjects was determined by random assignment.

For purposes of the AFHRL study, the 14 problems were further divided into maintenance levels for troubleshooting tasks. Ten of the problems were representative of intermediate level maintenance troubleshooting tasks and the remaining four were representative of organizational level maintenance troubleshooting tasks (30:20). The organizational maintenance level refers to those problems which might be encountered in flightline maintenance and the intermediate level refers to problems encountered in shop maintenance. Since this analysis is not concerned with the maintenance level of troubleshooting tasks, both types of problems were considered equally in terms of performance.

For each troubleshooting problem, the test administrator prepared the test equipment by completing the "pretest setup" according to the Test Administrator's Guide which was provided for him (30:40). He also verified that the necessary support materials for each problem were available. The subject was then brought into the troubleshooting

situation and given an instructions sheet and the work order which described the problem he was to troubleshoot.

The troubleshooting evaluation was conducted with one test administrator to one subject. The test administrator recorded data on subject performance using such measures as time, errors, parts consumed, successful completion of each section, correctness in following the technical documentation, and success in troubleshooting the problem (30:40). The test administrator was instructed not to answer procedural questions during the test.

In an operational situation, troubleshooting frequently involves removal and replacement of suspected parts and components, which equates to a trial and error method of isolating the fault (30:41). Since such a procedure would have exposed the test equipment to unnecessary abuse and possibly caused total failure, at no time was the subject allowed to repair any of the equipment. In the test situation, when a subject indicated that he would remove and replace a specific component which was not at fault, he was instructed to assume that he had done so and to continue. Standard times were derived for removal and replacement of the so identified components and these times were added to subject times to obtain a total elapsed time to fault isolation (30:41).

MAC Subjects: The subjects for the second two groups were obtained from operational units at McChord,

Travis, and McGuire Air Force Bases (30:42). Since the units at these three sites were operating on a three-shift day, subjects from each of the three shifts were used to obtain the required sample sizes. Each subject participated in the evaluation for four hours each day for a two-week period.

Proficiency tests evaluating a subject's ability to use specific items of the test equipment were administered on a selective basis. Since it was believed that an experienced technician could realistically assess his own familiarity with a specific item of test equipment, each subject was presented with a list of test equipment and asked to rank his ability to use each of the items (30:43). Proficiency tests were administered only when the subject indicated a questionable proficiency or when past experience indicated that increased familiarity with an item of test equipment was needed.

The MAC subjects were exposed to the full set of 15 equipment faults. Again, the faults were divided into maintenance levels with four faults being representative of organizational level maintenance troubleshooting tasks and the remaining 11 being representative of intermediate level maintenance troubleshooting tasks (30:44). As with the Keesler group, the maintenance level was not of primary concern in this analysis. Each fault was isolated an equal number of times with the T.O., LTTA, and FPTA

documentation. The order in which the documentation types (T.O., LTTA, or FPTA) were assigned to problems was determined by random selection.

The testing procedure followed at each MAC base was dependent upon the agreements reached with base personnel. Once the base requirements were established, a procedure was designed so that a standard approach to each subject on the base was maintained (30:57). To the extent possible, the procedure at each MAC base was the same and conformed as nearly as was practical to the Keesler testing procedure. Variances in procedures from base to base were primarily administrative with respect to access to technicians and physical facilities (30:57). In all cases, once the subject was placed in the troubleshooting situation, he was treated in an identical manner to Keesler subjects and the same measures of performance were obtained.

Description of Variables

The variables of primary concern in Research Proposition No. 1 are troubleshooting performance and type of troubleshooting aids. An intensive review of related literature failed to reveal any standard method of quantifying troubleshooting performance. From the review of research dealing with troubleshooting tasks and interviews with experts, it seems that the most generally accepted method of measuring troubleshooting performance is in terms

of time (6:13; 20; 21; 22:38; 39). Therefore, for purposes of this research, troubleshooting performance is defined as an average time per troubleshooting problem solved. The measure was derived from the performance data collected for the AFHRL project. Total time was found by summing the times spent on each problem (whether solved or not) with a particular type of troubleshooting aid. The total time included the additional time added to a subject's time for incorrect/unnecessary replacement of parts or components. The total time was then divided by the number of problems solved correctly with that type of aid to derive an average time per problem solved with that aid. This performance measure was computed for each subject in the three groups with each type of aid used. The formulation of the performance index was as follows:

$$PI = \frac{\sum T}{n_c}$$

where PI = performance index,

T = times spent on all problems and average times to remove and replace components incorrectly identified as faulty, and

n_c = number of problems solved correctly ($n_c \geq 1$).

The types of troubleshooting aids used were LTTAs, FPTAs, and T.O.s, which are described in the summary of the AFHRL project (Chapter II, pp. 35-38).

Design to Test Research
Proposition No. 1

The first research proposition (i.e., individuals who perform well using one type of troubleshooting aid, tend to perform well using the other types of troubleshooting aids), was tested by means of three separate hypothesis tests; one hypothesis test for each of the three experience levels sampled. The nonparametric Friedman two-way analysis of variance by ranks test was used to test each hypothesis. The null hypothesis (H_0) for each test was that there is no difference in the mean ranks of subjects using various troubleshooting aids. The alternate hypothesis (H_1) was that there are differences among the mean ranks of performances of individuals. The zero-experience-level group (Keesler graduates) were ranked according to performance with only the LTTA and the FPTA. The six-months-or-less-experience group and the more-than-six-months-experience group were ranked using all three aids.

Friedman Two-Way Analysis of Variance by Ranks Test. The Friedman Test required that the sample data be in at least an ordinal scale (37:166). The sample data for this research consisted of the previously described performance rating which is on a ratio scale. The only assumption necessary for the Friedman test is that the observations are independent and that the variables under study have underlying continuity (37:31). The data was

placed in a two-way table having N rows and k columns (37:166). The rows represent the type of troubleshooting aid used and the columns represent the 18 subjects in the groups. Each row shows the rank of the subject's performance, with that aid, relative to the other 17 subjects. The Friedman test determines if the columns of ranks came from the same population by determining whether the rank totals differ significantly (37:168). To make this test, the value of a statistic denoted as χ_r^2 must be computed. Since it can be shown that χ_r^2 is distributed approximately as chi square, the chi square tables were used for tests of significance (37:168). The level of significance (α) was set at .05.

These are the steps which were used in the Friedman two-way analysis of variance by ranks (37:171):

1. The performance scores for the subjects from the experience level being considered were cast in a two-way table having 18 columns and 2 rows for the Keesler subjects, or 3 rows for the MAC subjects.

2. The performance ratings in each row were ranked from 1 to 18.

3. The ranks in each column were then summed.

4. The test statistic was computed using the following formula:

$$\chi_r^2 = \frac{12}{Nk(k+1)} \sum_{j=1}^{k} (R_j)^2 - 3N(k+1)$$

where N = number of rows,

k = number of columns,

R_j = sum of ranks in j^{th} column, and

$\sum_{j=1}^{k}$ = the sum of the squares of the sums of ranks over all k.

5. The associated probability of occurrence under H_0 associated with the computed value of χ_r^2 was determined by reference to the chi-square distribution with $df = k-1$.

6. If the probability given by the chi-square distribution is equal to or less than α (.05), then H_0 was rejected.

Criterion Test

The objective of Research Proposition No. 1 was to show that there are individuals who possess native troubleshooting ability. The Friedman test was used to determine if there were significant differences among the rankings of the subjects in each sample group. In order to infer that certain subjects possessed native troubleshooting ability, a criterion test was also needed. The criterion upon which an inferrence of native troubleshooting ability could be made was that a statistically significant difference among the mean ranks of performance of the subjects must be shown for all three sample groups.

Research Proposition No. 2

Data Collection

The troubleshooting performance data, as described for Research Proposition No. 1, was also used in the analysis of Research Proposition No. 2.

Description of Variables

The variables of primary concern here are performance and experience level. Since a single performance measure was needed for each subject, individual performance indices for each type of troubleshooting aid were averaged. Thus, an average performance index was formulated as follows:

$$AP = \frac{\sum_{i=1}^{n} PI_i}{n}$$

where AP = average performance index,

PI = performance index previously computed for the i^{th} troubleshooting aid, and

n = number of types of troubleshooting aids with which the subject was evaluated (2 or 3).

This average performance index provided a single performance measure for each subject.

Three different experience levels of the 328X4 AFSC were sampled for the AFHRL project. The first group consisted of recent graduates of the Avionics Inertial and

Radar Navigation Systems Specialist Technical Training Course at KTTC. These subjects had no field experience. The second group consisted of MAC personnel who had six months or less experience in the career field. The third group was composed of MAC personnel with more than six months experience.

Design to Test Research Proposition No. 2

The objective of the second research proposition was to determine if a significant difference exists among the troubleshooting performance of technicians at the three different experience levels. The Kruskal-Wallis one-way analysis of variance by ranks was used to determine if differences existed between the experience levels. The Kruskal-Wallis technique is a nonparametric test used for deciding whether two or more samples are from different populations (37:184). The null hypothesis (H_0) for the test was that there is no difference between the average performance indices of technicians with no experience, technicians with six months or less experience, and technicians with more than six months experience. The alternate hypothesis (H_1) was that there is a difference in the average performance indices of the three groups.

Kruskal-Wallis One-Way Analysis of Variance by Ranks. The Kruskal-Wallis test requires that the variable

under study be in at least an ordinal scale (37:184). The sample data which was used in this analysis is on a ratio scale

For the analysis, the average performance indices for all 54 subjects were ranked in a single series (37:185). After the indices had been ranked, the sum of the ranks for each experience level was computed. The Kruskal-Wallis test determines whether these sums of ranks are significantly different.

The steps which were used in the Kruskal-Wallis test are summarized as follows (27:192):

1. All of the performance indices for the three sample groups were ranked in a single series, with ranks assigned from 1 to 54.

2. The sum of the ranks for each experience level was determined.

3. The test statistic, H, was computed as follows:

$$H = \frac{12}{N(N+1)} \sum_{j=1}^{k} \frac{R_j^2}{n_j} - 3(N+1)$$

where k = number of samples (i.e., experience levels),

n_j = number of cases in j^{th} sample,

$N = \sum nj$, the number of cases in all samples combined,

R_j = sum of ranks in j^{th} sample, and

$\sum_{j=1}^{k}$ directs one to sum over the k samples.

4. It can be shown that if the samples actually are from the same population or identical populations, then H is distributed as chi square with $df = k\text{-}1$ (37:185). Therefore, the significance of a value as large as the observed value of H was assessed by reference to the chi square table with $df = k\text{-}1$.

5. The level of significance (α) for this analysis was set at .05. If the probability associated with the observed value of H is equal to or less than α, H_0 was rejected.

When ties occurred between one or more indices, each index was given the mean of the ranks for which it was tied (37:188). Since the value of H is somewhat influenced by ties, the Kruskal-Wallis test allows a correction for a large number of ties. To correct for ties, H is computed as shown in step 3 and then divided by (37:188):

$$1 - \frac{\sum_T}{N^3-N}$$

where $T = t^3-t$ (t is the number of tied observations in a tied group of scores),

N = number of observations in all k samples together, and

$\sum T$ directs one to sum over all groups of ties.

The effect of correcting for ties is to increase the value of H and make the results more significant than if uncorrected.

Criterion Test

Research Proposition No. 2 attempts to determine if significant differences exist in level of performance at different experience levels. The analysis was performed at a significance level of .05. If H_0 is rejected at a = .05, then it could be inferred that the level of experience does make a significant difference in performance and further analysis of the data must consider each group separately.

Research Proposition No. 3

Data Collection

The subjects at Keesler were available to participate in the AFHRL experiment for the entire day for a two-week period. Each subject was scheduled for troubleshooting evaluation for only one-half of each day (30:30). The half-day committed to this evaluation was alternated in an attempt to remove any time-of-day effect of a particular problem, troubleshooting aid type, or subject. The

one-half day not involved with troubleshooting was used to collect ancillary data, such as information on the individual's background, personality, attitude, and aptitude. This research is primarily concerned with the personality data.

With the MAC sample groups, ancillary data was obtained at any time the subject was available and was not required for troubleshooting evaluation activities (30:57). This procedure was necessary since the MAC subjects were made available for only four hours each day. Identical ancillary data to that collected with the Keesler subjects was obtained.

The personality test which was administered during the AFHRL project was a 476-item Adjustment Prediction Inventory developed by Norman R. Potter (30:31). Imbedded in this inventory is the Gordon Personal Profile and the Gordon Personal Inventory Instruments. This research was concerned with those personality traits measured by the two Gordon instruments.

Personality Assessment Instruments

The Gordon Personal Profile measures four separate aspects of personality which are significant in the daily functioning of the normal person (16:3). The four traits measured are Ascendancy, Responsibility, Emotional Stability, and Sociability. These four traits are relatively

independent and psychologically meaningful traits which have been found to be important in determining the adjustment and effectiveness of an individual in many social, educational, and industrial situations (16:3).

The Profile is made up of eighteen sets of four descriptive phrases. Each set of four phrases is known as a "tetrad" (16:3). Each of the four personality traits is represented by one of the descriptive phrases in each tetrad. The respondent is asked to mark one item in each tetrad as being most like himself and one as being least like himself.

The Gordon Personal Inventory measures four additional traits and is used as a companion instrument with the Personal Profile (15:3). The traits measured are Cautiousness, Original Thinking, Personal Relations, and Vigor. Both the Inventory and the Profile may be used with high school, college, industrial, or general adult groups. The format of the Inventory is the same as that of the Profile except that the Inventory consists of twenty sets of tetrads. Both instruments make use of the forced-choice technique; that is, the respondent must mark the phrase most like and least like himself in each tetrad. Since the respondent can not respond favorably to all four items, the forced-choice approach is believed to be less susceptible to distortion by individuals who are motivated to make a good impression (15:3).

Validity and Reliability of Instruments

Both the Personal Profile and the Personal Inventory are accepted personality assessment instruments whose validity and reliability have been established through various studies (15:10; 16:10). These instruments have achieved wide usage in industrial personnel selection (16:15). The Gordon instruments were deemed appropriate for the AFHRL project because they are easily administered, scored, and interpreted (31). The tests are virtually self-administering and can be completed in 10 to 15 minutes. Additionally, the lack of correlation with intelligence and aptitude measures allows the Gordon instruments to make an independent contribution in predicting performance criteria (16:15).

Description of Variables

Research Proposition No. 3 dealt with correlating troubleshooting performance with the personality traits measured by the Gordon instruments in an attempt to identify those traits which can be used as predictors of success in troubleshooting tasks. The performance variable consisted of an average performance index for each subject. The procedure was to take the performance ratings computed for each type of troubleshooting aid for each subject for the first proposition and average those ratings. The result was a single performance measure for each subject.

These performance measures were then correlated with the scores obtained from the Gordon personality tests. •

A total of eight personality traits were measured by the Gordon instruments. The following is a description of these eight traits in terms of the interpretation of high and low scores (15:3; 16:3).

1. Ascendancy. Those individuals who are verbally ascendant, adopt an active role in the group, are self-assured and assertive in relationships with others, and tend to make independent decisions, score high on this scale. Those who play a passive role in the group, listen rather than talk, lack self-confidence, let others take the lead, and tend to be overly dependent on others for advice, normally make low scores.

2. Responsibility. The high scores on this scale are those individuals who are persevering and determined, are able to stick to any job assigned them, and can be relied on. Individuals who are unable to stick to tasks that do not interest them, and who tend to be irresponsible usually score low.

3. Emotional Stability. High scores on this scale are generally made by individuals who are well-balanced, emotionally stable, and relatively free from anxieties and nervous tension. Low scores are associated with excessive anxiety, hypersensitivity, nervousness, and low frustration

tolerance. Generally a very low score reflects poor emotional balance.

4. Sociability. High scores are made by individuals who like to be with and work with people, and who are gregarious and sociable. Low scores reflect a lack of gregariousness, a general restriction in social contacts, and, in the extreme, an actual avoidance of social relationships.

5. Cautiousness. Individuals who are highly cautious, who consider matters very carefully before making decisions, and do not like to take chances or run risks, score high on this scale. Those who are impulsive, act on the spur of the moment, make snap decisions, enjoy taking chances, and seek excitement, score low.

6. Original Thinking. High scoring individuals like to work on difficult problems, are intellectually curious, enjoy thought-provoking questions and discussions, and like to think about new ideas. Low scoring individuals dislike working on difficult or complicated problems, do not care about acquiring knowledge, and are not interested in thought-provoking questions or discussions.

7. Personal Relations. High scores are made by those individuals who have great faith and trust in people, and are tolerant, patient, and understanding. Low scores reflect a lack of trust or confidence in people, and a

tendency to be critical of others and to become annoyed or irritated by what others do.

8. Vigor. High scores on this scale characterize individuals who are vigorous and energetic, who like to work and move rapidly, and who are able to accomplish more than the average person. Low scores are associated with low vitality or energy level, a preference for setting a slow pace, and a tendency to tire easily and be below average in terms of sheer output or productivity.

Design to Test Research Proposition No. 3

The third research proposition, that a relationship exists between troubleshooting performance and personality characteristics, was tested by means of eight separate hypothesis tests; one test for each of the eight traits measured by the Gordon instruments. The statistical technique used was the nonparametric Spearman rank correlation coefficient. The null hypothesis (H_0) for each test was that the performance ratings and the personality scores are not related. The alternate hypothesis (H_1) was that the two variables are related.

Spearman Rank Order Correlation Coefficient. The Spearman test is a measure of association which requires that the variables be in at least an ordinal scale (37: 202). The performance variable for this research was on a

ratio scale and the personality test scores were on an ordinal scale.

For the Spearman test the subjects were ranked in a two-ordered series according to performance index and personality trait score (37:202). The steps necessary in the use of the Spearman rank correlation coefficient for each group are as follows (37:212):

1. The performance ratings and personality scores were each ranked from 1 to 54.

2. Each of the subjects was listed with his rank on the performance variable and the personality variable next to his entry.

3. The value of d_i was determined by subtracting the personality variable rank from the performance variable rank. This value was squared and summed to obtain $\sum d_i^2$.

4. The test statistic, r_s, was computed as follows:

$$r_s = 1 - \frac{6\sum_{i=1}^{N} d_i^2}{N^3 - N}$$

where d_i = difference in ranks of the two variables under study, and

N = number of subjects.

5. If the subjects consistute a random sample from some population, a test of significance can determine

whether the observed value of r_s indicates an association between the variables in the population. The significance of a value as large as the computed value of r_s may be determined by computing the t associated with the r_s value. The significance of that value of t can be determined by referring to the table of critical values of t. The value of t is computed by the formula:

$$t = r_s \sqrt{\frac{N-2}{1-r_s^2}}$$

where N = the total number of subjects, and

r_s = the computed correlation coefficient.

The value of t is distributed as Student's t with $df = N-2$.

When tied scores occurred, each of them was assigned the average of the ranks for which they were tied. If the proportion of ties in the Spearman test is not large, their effect on r_s is negligible and the formula described above may still be used (37:206). However, when the proportion of ties is large, a correlation factor must be used in the computation of r_s.

The correlation factor is calculated by:

$$T = \frac{t^3-t}{12}$$

where t = the number of tied observations at a given rank.

When a considerable number of ties were present, the following formula was used to compute r_s:

$$r_s = \frac{\sum x^2 + \sum y^2 - \sum d^2}{2\sqrt{\sum x^2 \sum y^2}}$$

where $\sum x^2 = \frac{N^3 - N}{12} \sum T_x$, and

$$\sum y^2 = \frac{N^3 - N}{12} \sum T_y .$$

Criterion Test

Research Proposition No. 3 was concerned with the identification of one or more personality variables which are related to troubleshooting performance. The significance level for testing the eight hypotheses for each group was set at .05. In order to support the research proposition, the criterion test was that a minimum of one personality variable needed to be found to be significantly related to troubleshooting performance.

Research Proposition No. 4

Data Collection

Since 1959, the Airman Qualifying Examination (AQE) has been the primary aptitude measure used for the

screening and for the classification of basic trainees for technical training (41:1).[1] The AQE consists of about 200 aptitude items and is designed to evaluate airmen in terms of four aptitude areas considered important for success in certain AF schools and airman career fields (42:12-1). Minimum scores in these aptitude areas are considered desirable for entry into certain career fields and for admission to certain AF technical training courses. Airmen who receive at least the minimum scores and are otherwise qualified are considered to have reasonable expectations of being successful in the training or duty for which the minimum score is specified (42:12-1). Although a number of factors enter into an airman's assignment, the most important is his score on the aptitude area appropriate to his broad career field (41:1). The AQE is composed of a series of subtests which are combined into four aptitude clusters: Mechanical, Administrative, Electronics, and General.

The AQE is composed of a total of 10 subtests. Each of the four aptitude clusters includes one or more of the subtests and each subtest may be included in more than one aptitude cluster. The following is a list of the aptitude clusters and the subtests in each cluster (44:2).

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[1]The AQE has since been changed to the Airman Classification Test (ACT); however, the ACT aptitude areas are comparable in magnitude and content to AQE scores on the same areas (42:12-1).

Mechanical

1. General Mechanics
2. Hidden Figures
3. Mechanical Principles
4. Shop Practices

Administrative

1. Arithmetic Computation
2. Arithmetic Reasoning
3. Word Knowledge

Electronics

1. Arithmetic Reasoning
2. Data Interpretation
3. Electrical Information
4. Pattern Comprehension

General

1. Arithmetic Reasoning
2. Hidden Figures
3. Word Knowledge

The AQE scores for the subjects in the AFHRL study were taken from the personnel records of each subject. Entry into the 328X4 AFSC career field, and therefore the KTTC training course, requires a score of at least 80 in the Electronics aptitude cluster of the AQE (43:A16-84). The Electronics score is the primary consideration for entry into the career field; however, for the sake of research, this analysis considered all four scores.

Description of Variables

Research Proposition No. 4 was concerned with correlating troubleshooting performance and aptitude measured by the AQE. The performance variable consisted of an

average performance index for each subject as described in Research Proposition No. 2. The aptitude variables consisted of the scores from each AQE aptitude cluster for each subject. What follows is a description of the aptitude variables in terms of what aspects of aptitude each of the AQE subtests measures (44:5).

1. Arithmetic Computation. This subtest consists of simple arithmetic items involving addition, subtraction, multiplication, and division of whole numbers. It is administered as a speed test and is designed to measure the ability to manipulate numbers rapidly and accurately.

2. Arithmetic Reasoning. This subtest evaluates the examinee's ability to think through mathematical problems presented in verbal form. It involves the discovery and application of the general mathematical principles required to arrive at a correct solution to each problem, as well as performance of the necessary calculation to attain that solution.

3. Data Interpretation. This subtest is designed to measure the ability to draw conclusions or make interpretations from data presented in the form of graphs, charts, and tables.

4. Electrical Information. The ability to apply previously acquired knowledge in the areas of electricity and electronics toward the solutions of practical problems is measured by this subtest.

5. General Mechanics. This subtest consists of verbal items relating to the understanding and application of basic techniques required for the troubleshooting and repair of various mechanical devices.

6. Hidden Figures. This subtest requires the examinee to determine which one of the five simple line drawings is contained in a more complex arrangement of geometric figures.

7. Mechanical Principles. In this subtest, the examinee is required to determine from pictures of mechanical devices their operating characteristics.

8. Pattern Comprehension. This subtest involves visualizing the folding of flat patterns into three-dimensional objects and subsequently determining the location of specific points which are common to both the pattern and the solid figure.

9. Shop Practices. This is a pictorial subtest which requires the examinee to identify pictured tools and determine their proper use in a specific situation or the selection of the proper tool for use in a given task.

10. Word Knowledge. This is a subtest of verbal ability involving the definition of words. It is a vocabulary test of nontechnical terms.

Design to Test Research Proposition No. 4

The fourth research proposition, that there is a direct relationship between troubleshooting performance and aptitude, was tested through four separate hypotheses tests; one test for each of the four aptitude scores from the AQE. The statistical technique used was the nonparametric Spearman rank correlation coefficient. The Spearman test was performed as described in Research Proposition No. 3. The null hypothesis (H_0) for each test was that the performance indices and the aptitude scores are not related. The alternate hypothesis (H_1) was that the two variables are related. The significance level for testing the four hypotheses for each group was set at .05.

Criterion Test

In order to support the research proposition, the criterion test was that at least one AQE aptitude cluster needed to be found to be significantly related to troubleshooting performance.

Summary List of Assumptions

1. The maintenance level of troubleshooting maintenance tasks is not significant.

2. The observations are independent, and the variables under study have underlying continuity.

3. The standard times derived for replacement of incorrect parts and components are representative times.

Summary List of Limitations

1. The researchers had no control over experiment design or data collection. The data was collected in a previous research project which had different, though not conflicting, objectives.

2. The performance criteria computations used in this research may not be appropriate for all troubleshooting situations.

3. The findings of this research can not be generalized outside the population of interest.

CHAPTER IV

ANALYSIS AND DISCUSSION

This chapter contains the statistical analysis and discussion of each Research Proposition. Discussion of the analysis of each proposition is included since the results were not as originally predicted. In some areas, additional analysis was conducted in an effort to gain greater insight into what factors might have caused the results to differ from what was predicted.

Consistency of Individual Performance Using Various Types of Aids

The first research proposition was that "Individuals who perform well using one type of troubleshooting aid, tend to perform well using the other types of troubleshooting aids." The objective of this proposition was to demonstrate that some of the subjects possessed a higher level of native troubleshooting ability than the others. To determine support or nonsupport for the proposition, Hypotheses 1 through 3 were tested using the Friedman two-way analysis of variance test. Thus, the following general hypothesis was tested for each experience-level subject group.

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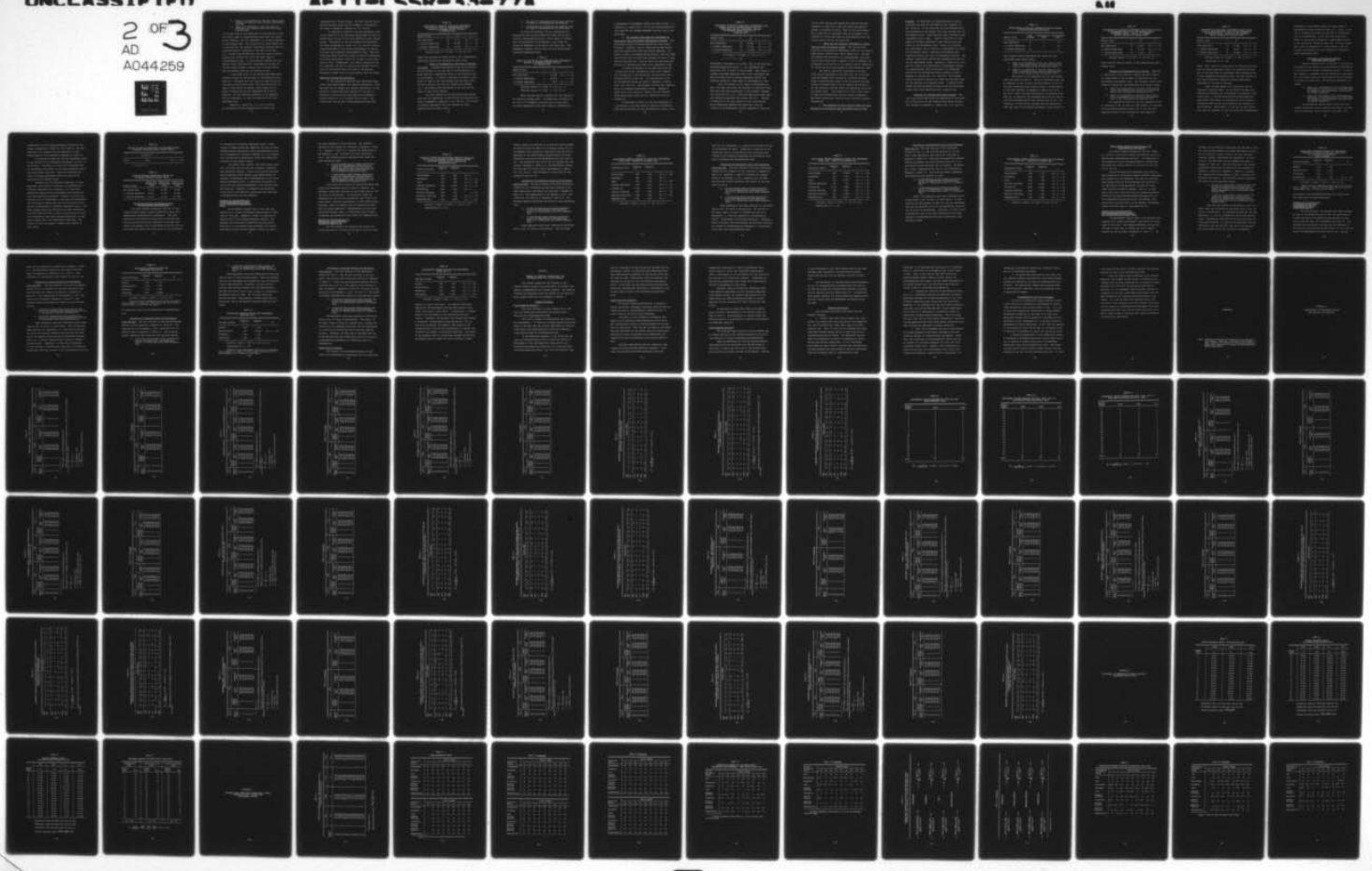

H_0: There is no difference in the mean ranks of performance of subjects using various troubleshooting aids.

H_1: There is a difference in the mean ranks of performance of subjects using various troubleshooting aids.

If the mean ranks of the performance of the subjects, across the various types of troubleshooting aids used, is significantly different, the null hypothesis, H_0, would be rejected by the Friedman test. The rejection of H_0 would enable one to conclude that the subjects' performance rankings were consistently similar, regardless of the type of aid used (i.e., subjects who perform well using one type of troubleshooting aid, perform well using the other types of troubleshooting aids). It could then be inferred that the subjects which performed well, regardless of the type of aid being used, possess a higher level of native ability than the subjects which did not perform as well.

On the other hand, if the subjects performed inconsistently across the various types of troubleshooting aid used (i.e., did quite well when using one type of aid, but very poorly using another type), then the distribution of ranks in each column (by subject) would appear to be a matter of chance and the null hypothesis would not be rejected. For the research proposition to be supported, the null hypothesis, H_0, must be rejected in all three hypothesis tests.

Appendix A, Tables A-1, A-2, and A-3 contain the performance indices computations for each of the

experience-level subject groups. The rank ordering within experience-level groups and the Friedman χ_r^2 computations are shown in Appendix A, Tables A-4, A-5, and A-6.

As indicated in Table 1A, the null hypothesis could not be rejected, at the previously established .05 level of significance, for any of the three experience-level subject groups. Examination of the rank ordering of performance (as shown in Appendix A, Tables A-4, A-5, and A-6) reveals large differences in the relative performance of individuals when using different troubleshooting aids. Some individuals performed quite well using one type of troubleshooting aid but quite poorly using one, or more, of the other types of aids. Consequently, the research proposition was not supported, and thus it could not be inferred from the data and statistical tests that some of the subjects possessed a higher level of native ability than the others.

Additional Analysis and Discussion

It was originally predicted that these three hypothesis tests would support the research proposition. Since the tests did not support the research proposition, it was decided to conduct additional analysis of the data to determine if native ability was merely being masked by certain factors or if it actually did not exist. The authors felt that several conditions/factors might have

TABLE 1A

CONSISTENCY OF RELATIVE INDIVIDUAL PERFORMANCE USING VARIOUS TYPES OF TROUBLESHOOTING AIDS: RESULTS OF FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST

Subject Group	N	χ_r^2	p
Zero Experience	18	21.123	$.20 < p < .30$
$\leq$ 6 Months Experience	18	15.450	$.50 < p < .70$
> 6 Months Experience	18	25.269	$.05 < p < .10$

Critical Value $\chi^2 = 27.587$, $\alpha = .05$, $df = 17$.

masked the existence of native ability, and, consequently, additional analysis was conducted in these areas.

1. Types of troubleshooting aid had an overpowering effect. A possible explanation of why native ability was not evident is that the type of troubleshooting aid being used had a significant effect on the subjects' overall performance. In order to determine the extent of the effect of type of aid, the Friedman test was again used. For this analysis, the rows and columns were reversed (i.e., the subjects were now placed in the rows and the types of aids in the columns).

The rank ordering of the aids within each subject group and the computation of the Friedman χ_r^2 statistics are shown in Appendix A, Tables A-7, A-8, and A-9. The following general hypothesis test was conducted for each experience-level subject group:

H_0: The type of troubleshooting aid being used had no effect on troubleshooting performance.

H_1: Troubleshooting performance was dependent upon the type of troubleshooting aid being used.

As Table 1B indicates, the null hypothesis was rejected for both the zero-experience group and the six-months-or-less-experience group. Thus, there is evidence that the performance of the subjects in the first two groups was dependent on the type of aid being used. This dependency, however, did not hold true for the more-than-six-months-experience group.

TABLE 1B

EFFECT OF TYPE OF AID ON TROUBLESHOOTING PERFORMANCE: RESULTS OF FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST

Subject Group	N	χ_r^2	p
Zero Experience	2	5.555[a]	$.01 < p < .02$
$\leq$ 6 Months Experience	3	21.333[b]	$p < .01$
> 6 Months Experience	3	.111[b]	$.90 < p < .95$

[a]Critical Value $\chi^2 = 3.841$, $\alpha = .05$, $df = 1$.

[b]Critical Value $\chi^2 = 5.991$, $\alpha = .05$, $df = 1$.

These findings seem to coincide with the results of the previous Friedman tests. An examination of Tables A-4, A-5, and A-6 in Appendix A reveals that the more-than-six-months-experience group came closest to demonstrating

a consistency of performance across all types of aids (i.e., rejecting H_0), which also indicates that the performance of this group was not strongly dependent upon the type of aid being used.

2. The standard times used for replacement of spare parts could have masked differences in ability. The performance indices initially computed for each subject included a "standard" time for replacing any spare parts which the subject would have erroneously replaced. If a subject actually did possess native ability, then the possibility exists that he could have replaced any parts in less than the standard time. Thus he would have been penalized unfairly by including this time in his performance index.

In order to determine if the spare-part time was a significant factor, performance indices were computed for the subjects in each group with the spare-part time excluded from the total time. The computations of the new performance indices are shown in Appendix A, Tables A-10, A-11, and A-12. The Friedman test was then conducted using the recomputed performance indices. Appendix A, Tables A-13, A-14, and A-15, contain the rank ordering within each subject group and the computations for the Friedman χ_r^2.

As indicated in Table 1C, the null hypothesis of no difference in the mean ranks of subjects' performance could not be rejected for the zero-experience group or the

TABLE 1C

CONSISTENCY OF RELATIVE INDIVIDUAL PERFORMANCE USING VARIOUS TYPES OF TROUBLESHOOTING AIDS WITH SPARE-PART TIME NOT CONSIDERED: RESULTS OF FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST

Subject Group	N	χ_r^2	p
Zero Experience	18	20.281	$.20 < p < .30$
$\leq$ 6 Months Experience	18	17.609	$.30 < p < .50$
> 6 Months Experience	18	27.725*	$.02 < p < .05$

Critical Value $\chi^2 = 27.587$, $\alpha = .05$, $df = 17$.

*Significant at $\alpha = .05$.

six-months-or-less-experience group. But for the more-than-six-months-experience group, the null hypothesis was rejected at the .05 level of significance. Thus, there is evidence that when spare-part time is not considered, subjects with more than six months experience perform consistently across all three types of troubleshooting aids.

Due to the nature of the types of troubleshooting aids, one might think that the exclusion of spare-part time would have been most significant in the subjects' performance using the T.O. (i.e., that more spare-parts would have been replaced erroneously while using the T.O.). However, a comparison of the rank ordering of the more-than-six-months-experience subjects when spare-part time was included in the performance indices (Appendix A, Table A-6)

and the rank ordering when spare-part time was excluded (Appendix A, Table A-15), does not reveal any specific pattern in changing of ranks. That is, the rank changes due to exclusion of spare-part time do not appear to be confined to a particular type of troubleshooting aid, but instead affect each of the three aids.

3. There was not sufficient difference in native ability within the subject groups. The time and cost involved in collecting the performance data for the original AFHRL project necessitated a small sample size. Although the samples were believed to be representative, the possibility exists that within a sample of only 18 subjects, the difference in the ability of the subjects was not sufficient for native ability to be revealed in the statistical tests.

The lack of sufficient differences in ability could also be attributed to the fact that all of the subjects had already been screened by a selection process based on aptitude test scores in the Electronics aptitude cluster (a minimum score of 80 is required for selection for the technical training course and subsequent entry into the career field). Since there was no way to test either of these two possibilities without actually conducting additional evaluations, they are merely stated as possible explanations.

4. The existence of native ability might have been masked by not considering the maintenance level of test

problems. In describing the testing procedures used in collecting the data for the AFHRL project (Chapter III, pps. 48-49,51), it was noted that the test problems which were presented to each subject group were divided into two maintenance levels: organizational level (flightline) and intermediate level (shop). Table 1D shows how the total number of problems presented to each subject group was broken out by maintenance level. Since it is possible that individuals vary in ability to troubleshoot at different maintenance levels, individual performances were reanalyzed holding the level of maintenance constant. The subjects' performance indices were recomputed for each of the two maintenance levels. Appendix A, Tables A-16, A-17, and A-18 contain the computations of performance indices for organizational level maintenance; the performance indices for the intermediate-level problems as shown in Appendix A, Tables A-22, A-23, and A-24. The Friedman two-way analysis of variance by ranks test was again used for the analysis by maintenance level. A separate hypothesis test was conducted for each of the two maintenance levels within each experience-level subject group.

Analysis of Organizational-Level Problems. The rank order within each group and computation of the Friedman χ_r^2 statistics for the organizational-level problems are contained in Appendix A, Tables A-19, A-20, and A-21.

TABLE 1D

ORGANIZATIONAL LEVEL AND INTERMEDIATE LEVEL PROBLEMS FOR EACH EXPERIENCE-LEVEL GROUP

Subject Group	Total Problems	Organizational Level	Intermediate Level
Zero Experience	14	4	10
$\leq$ 6 Months Experience	15	4	11
> 6 Months Experience	15	4	11

The Following general hypothesis was tested for each experience-level subject group:

H_0: There is no difference in the mean ranks of subjects' performance using various troubleshooting aids at the organizational maintenance level.

H_1: There is a difference in the mean ranks of subjects' performance using various troubleshooting aids at the organizational maintenance level.

The results of the hypotesis test for each subject group are shown in Table 1E. The null hypothesis could not be rejected, at the .05 level of significance, for any of the three experience-level subject groups. An examination of the rank orderings in Appendix A, Tables A-19, A-20, and A-21, reveals the same conditions as in previous tests. That is, an individual who performed well with one type of aid often performed poorly with another type of aid. Consequently, it could not be inferred from the statistical test that some of the subjects possessed a higher level of

TABLE 1E

CONSISTENCY OF INDIVIDUAL PERFORMANCE USING VARIOUS TYPES OF TROUBLESHOOTING AIDS AT THE ORGANIZATIONAL MAINTENANCE LEVEL: RESULTS OF FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST

Subject Group	N	χ_r^2	p
Zero Experience	18	16.035	$.50 < p < .70$
$\leq$ 6 Months Experience	18	21.795	$.10 < p < .20$
> 6 Months Experience	18	6.833	$.99 < p$

Critical Value $\chi^2 = 27.587$, $\alpha = .05$, $df = 17$.

native ability than did others at the organizational maintenance level.

Analysis of Intermediate-Level Problems. Appendix A, Tables A-25, A-26, and A-27, contain the rank ordering and computations of the Friedman χ_r^2 statistics for the intermediate maintenance level. The following general hypothesis was tested for each experience-level subject group:

H_0: There is no difference in the mean ranks of subjects' performance using various troubleshooting aids at the intermediate maintenance level.

H_1: There is a difference in the mean ranks of subjects' performance using various troubleshooting aids at the intermediate maintenance level.

As indicated in Table 1F, the null hypothesis could be rejected, at the .05 level of significance, for the more-than six-months-experience group, but not for the zero-experience group or the six-months-or-less-experience

TABLE 1F

CONSISTENCY OF INDIVIDUAL PERFORMANCE USING VARIOUS TYPES OF TROUBLESHOOTING AIDS AT THE INTERMEDIATE MAINTENANCE LEVEL: RESULTS OF THE FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST

Subject Group	N	χ_r^2	p
Zero Experience	18	23.895	$.10 < p < .20$
$\leq$ 6 Months Experience	18	18.251	$.30 < p < .50$
> 6 Months Experience	18	30.288*	$.02 < p < .05$

Critical Value $\chi_r^2 = 27.587$, $\alpha = .05$, $df = 17$.

*Significant at $\alpha = .05$.

group. Thus, there is evidence that for subjects with more than six months experience, there is a significant difference in the mean ranks of performance when troubleshooting at the intermediate maintenance level, and that subjects in this group maintained consistent relative performance regardless of the type of aid used.

These findings appear to be consistent with the findings of previous tests. In the initial Friedman test conducted to determine the consistency of performance using various aids, it was the more-than-six-months-experience group which came closest to rejecting the null hypothesis (reference Table 1A) and thus supporting the existence of native ability. Additionally, in the test in which spare-part time was excluded, it was this group which demonstrated

consistency of performance across all three types of troubleshooting aids (reference Table 1C). Again, in the test to determine the effect of the type of troubleshooting aid on performance, it was this same group which showed no significant differences in performance related to the type of aid (reference Table 1B). It would appear, then, from the combination of these results, that consistency of performance is more evident for subjects at higher experience levels.

Difference in Performance Between Experience-Level Groups

Research Proposition No. 2 was that "A significant difference exists between the troubleshooting performances of technicians of different experience levels." To determine support or nonsupport for the proposition, Hypothesis No. 4 was tested using the Kruskal-Wallis one-way analysis of variance by ranks test. The following hypothesis was tested:

H_0: There is no difference in the troubleshooting performance of technicians with no experience, six months or less experience, and more than six months experience.

H_1: There is a difference in the troubleshooting performance of technicians with no experience, six months or less experience, and more than six months experience.

The performance indices used in this test were average performance indices computed by averaging the subjects' performance over all types of aids used. The

computations of the average performance indices are contained in Appendix B, Tables B-1, B-2, and B-3. The rank ordering of the subjects and the computation of the Kruskal-Wallis *H* are contained in Appendix B, Table B-4.

As indicated in Table 2A, the null hypothesis could not be rejected at the previously established .05 level of significance. Therefore, it could not be concluded that the performance of subjects at the three experience levels was significantly different. Table 2B illustrates the range of average performance indices for each of the experience-level subject groups.

Although this test indicates otherwise, it would seem that there would be a difference in performance of different experience-level subjects (i.e., that more experienced subjects would troubleshoot more effectively than less experienced subjects). However, a further consideration of the differences in the types of troubleshooting aids helps to explain why this test indicates no difference in performance at different experience levels. The basic premise behind the proposed use of more proceduralized aids (FPTA and LTTA) is that a technician with little or no experience, when using proceduralized aids, can perform as effectively as an experienced technician. The results of this test appear to support that premise to some extent.

TABLE 2A

RESULTS OF TEST FOR DIFFERENCE IN PERFORMANCE AMONG DIFFERENT EXPERIENCE-LEVEL SUBJECT GROUPS

H	Critical χ^2	p
3.850	5.991	$.10 < p < .20$

$\alpha = .05$, $df = 2$.

TABLE 2B

RANGE OF AVERAGE PERFORMANCE INDICES FOR DIFFERENT EXPERIENCE-LEVEL GROUPS

Subject Group	Lowest Avg. Performance Index	Median Avg. Performance Index	Highest Avg. Performance Index
Zero Experience	33.170	51.825	74.681
$\leq$ 6 Months Experience	20.002	43.133	78.233
> 6 Months Experience	19.578	34.542	117.224

Relationship Between Personality Traits and Troubleshooting Performance

The third research proposition was that "A relationship exists between specific personality traits and demonstrated troubleshooting performance." When this proposition was originally constructed, it was believed that statistical tests would demonstrate that some technicians did possess native troubleshooting ability and also that there were significant differences in the performance

of technicians at different experience levels. Since neither of these beliefs was supported, the test for relationship between personality traits and performance could not be conducted as originally intended (i.e., by conducting a correlation of personality traits with average performance for each subject group).

The authors felt, however, that some insight could still be gained from the data and, therefore, conducted some additional analysis. First, since the more-than-six-months-experience-level subject group demonstrated consistency of performance when troubleshooting at the intermediate maintenance level, a correlation of personality traits with the average performance of this subject group was conducted. Secondly, a correlation of personality traits with all the subjects' performance with each type of troubleshooting aid was conducted.

Analysis of the More-Than-Six-Months-Experience-Level Group at the Intermediate Maintenance Level

The performance indices used in this test were computed as an average performance index across all three types of aids used. Appendix C, Table C-1 contains the computations of the average performance indices. The Spearman rank correlation coefficient test was used to determine if a relationship existed between the average performance indices and the subjects' scores for each of

the eight personality traits measured. The subjects' personality test scores are contained in Appendix C, Table C-3. Appendix C, Table C-4, contains the computations of the Spearman r_s and t statistics for each personality trait. The following general hypothesis was tested for each personality trait:

H_0: No relationship exists between personality traits and demonstrated troubleshooting ability of technicians with more than six months experience when troubleshooting at the intermediate maintenance level.

H_1: A relationship exists between personality traits and demonstrated troubleshooting ability of technicians with more than six months experience when troubleshooting at the intermediate maintenance level.

Since there was no basis for predicting whether any existing relationship would be direct or indirect, the hypothesis tests were conducted as two-tailed tests at the .05 level of significance. As indicated in Table 3A, Responsibility was the only personality trait found to be significantly related to performance in this subject group. Therefore, there is evidence that for subjects with more than six months experience, troubleshooting at the intermediate maintenance level, a relationship exists between performance and personality test scores for Responsibility.

Analysis of the Correlation of Personality Traits with Performance by Type of Aid

For this analysis the subjects were placed into groups according to the type of aid used so that the three

TABLE 3A

RESULTS OF TESTS FOR RELATIONSHIP BETWEEN PERSONALITY TRAITS AND PERFORMANCE OF MORE-THAN-SIX-MONTHS-EXPERIENCE SUBJECT GROUP--INTERMEDIATE MAINTENANCE LEVEL

Personality Trait	Computed r_s	Computed t	p
Cautiousness	.016	.062	$.90 < p$
Ascendancy	.214	.878	$.30 < p < .40$
Vigor	.161	.625	$.50 < p < .60$
Personal Relations	-.294	-1.229	$.20 < p < .30$
Sociability	-.002	- .008	$.90 < p <$
Original Thinking	.098	.392	$p = .70$
Emotional Stability	.146	.589	$.50 < p < .60$
Responsibility	.516	2.407*	$.02 < p < .05$

Critical t value = $\pm$ 2.120, α = .05, df = 16.

*Significant at α = .05.

subject groups now consisted of 54 subjects using the FPTA, 54 subjects using the LTTA, and 36 subjects using the T.O. The Spearman rank correlation coefficient test was used to determine if any relationships existed between the eight personality test scores and performance with each type of aid. The personality test scores for all subjects are contained in Appendix C, Table C-2. The performance indices for each type of aid were taken from Appendix A, Tables A-1, A-2, and A-3. The following is a discussion of the analysis by type of aid.

Correlation of Personality Traits and Performance Using the FPTA. The rank ordering of the FPTA performance indices for all 54 subjects and the rank ordering of the eight personality test scores are contained in Appendix C, Table C-5. The computations of the Separman r_s and t statistics for the FPTA are in Appendix C, Table C-6. The following general hypothesis was tested for each personality trait:

H_0: No relationship exists between personality traits and demonstrated troubleshooting ability of technicians using FPTA documentation.

H_1: A relationship exists between personality traits and demonstrated troubleshooting ability of technicians using FPTA documentation.

These hypothesis tests were conducted as two-tailed tests at the .05 level of significance. Table 3B shows

TABLE 3B

RELATIONSHIP BETWEEN PERSONALITY TRAITS AND PERFORMANCE USING FPTA: RESULTS OF SPEARMAN TEST

Personality Trait	Computed r_s	Computed t	p
Cautiousness	.027	.195	$.80 < p < .90$
Ascendancy	.041	.103	$.90 < p$
Vigor	.051	.366	$.70 < p < .80$
Personal Relations	-.064	-.461	$.60 < p < .70$
Sociability	-.109	-.786	$.40 < p < .50$
Original Thinking	-.063	-.448	$.60 < p < .70$
Emotional Stability	-.029	-.205	$.80 < p < .90$
Responsibility	-.012	-.083	$.90 < p$

Critical t Value = $\pm$ 2.10, α = .05, df = 51.

that the null hypothesis, H_0, could not be rejected for any of the personality traits. Therefore it could not be concluded that any of the personality traits measured were related to the subjects' troubleshooting performance using Fully Proceduralized Troubleshooting Aids.

Correlation of Personality Trait and Performance Using the LTTA. The rank ordering of the LTTA performance indices for all subjects is also contained in Appendix C, Table C-5. Appendix C, Table C-7 contains the computations of the Spearman r_s and t statistics for the LTTA. The following general hypothesis was tested for each personality trait:

H_0: No relationship exists between personality traits and demonstrated troubleshooting ability of technicians using LTTA documentation.

H_1: A relationship exists between personality traits and demonstrated troubleshooting ability of technicians using LTTA documentation.

These hypothesis tests were conducted as two-tailed tests at the .05 level of significance. The results of the tests, shown in Table 3C, indicate that the null hypothesis, H_0, could be rejected for two personality traits: Cautiousness and Emotional Stability. Therefore, there is evidence that Cautiousness and Emotional Stability are related to troubleshooting performance of technicians using Logic Tree Troubleshooting Aids.

TABLE 3C

RELATIONSHIP BETWEEN PERSONALITY TRAITS AND PERFORMANCE USING LTTA: RESULTS OF SPEARMAN TEST

Personality Trait	Computed r_s	Computed t	p
Cautiousness	.348	2.654*	$.01 < p < .02$
Ascendancy	.131	.947	$.30 < p < .40$
Vigor	.171	1.236	$.20 < p < .30$
Personal Relations	.105	.751	$.40 < p < .50$
Sociability	-.137	-.986	$.30 < p < .40$
Original Thinking	.190	1.382	$.10 < p < .20$
Emotional Stability	.331	2.506*	$.01 < p < .02$
Responsibility	.211	1.537	$.10 < p < .20$

Critical t value = $\pm$ 2.01, α = .05, df = 51.

*Significant at α = .05.

Correlation of Personality Traits and Performance Using the T.O. The rank ordering of the performance indices for the T.O. and the rank ordering of the subjects' eight personality test scores are contained in Appendix C, Table C-8. Since the zero-experience subjects (Keesler graduates) were not evaluated using the T.O.s, this subject group contained only 36 subjects. The Spearman r_s and t computations for the T.O. are contained in Appendix C, Table C-9. The following general hypothesis was tested for each personality trait:

H_0: No relationship exists between personality traits and demonstrated troubleshooting ability of technicians using T.O. documentation.

H_1: A relationship exists between personality traits and demonstrated troubleshooting ability of technicians using T.O. documentation.

Again, the hypothesis tests were conducted as two-tailed tests at the .05 level of significance. As indicated by the test results in Table 3D, the null hypothesis could not be rejected for any of the personality traits at the .05 level of significance. Therefore, it could not be concluded that any of the eight personality traits were related to troubleshooting ability of technicians using Technical Orders.

TABLE 3D

RELATIONSHIP BETWEEN PERSONALITY TRAITS AND PERFORMANCE USING T.O.: RESULTS OF SPEARMAN TEST

Personality Trait	Computed r_s	Computed t	p
Cautiousness	.286	1.742	$.05 < p < .10$
Ascendancy	-.139	-.819	$.40 < p < .50$
Vigor	.064	.374	$.70 < p < .80$
Personal Relations	-.293	-1.888	$.05 < p < .10$
Sociability	-.268	-1.625	$.10 < p < .20$
Original Thinking	-.042	- .244	$.80 < p < .90$
Emotional Stability	.165	.976	$.30 < p < .40$
Responsibility	.324	1.990	$.05 < p < .10$

Critical t Value = $\pm$ 2.034, α = .05, df = 34.

Relationship Between Aptitude Scores and Troubleshooting Performance

The fourth research proposition was that "There is a positive relationship between AQE aptitude scores and demonstrated troubleshooting ability." The objective of this proposition was to determine whether a technician's AQE scores are a good predictor of how well he will perform on the job.

Since the propositions regarding native ability and differences in performance between different experience-level groups were not supported, the tests for relationships between aptitude and performance were conducted in the same manner as the personality correlation tests, rather than as originally intended. That is, the AQE scores were first correlated with the average performance indices of the more-than-six-months-experience group of the intermediate maintenance level, and secondly, AQE scores were correlated with all the subjects' performance indices with each type of troubleshooting aid.

Analysis of the More-Than-Six-Months-Experience-Level Group at the Intermediate Maintenance Level

The performance indices used in this analysis were computed as an average performance index across all three types of aids used. The average performance indices were the same as those used in testing the third research proposition and are shown in Appendix C, Table C-1. The

Spearman rank correlation coefficient test was used to test for relationships between the average performance indices and the subjects' scores in each of the four aptitude clusters: General, Administrative, Mechanical, and Electronics. The AQE scores for all subjects are shown in Appendix D, Table D-1. The rank ordering of the average performance indices and the AQE scores are contained in Appendix D, Table D-2. Appendix D, Table D-3, contains the computations of the Spearman r_s and t statistics for each aptitude cluster. The following general hypothesis was tested for each aptitude cluster:

H_0: No positive relationship exists between AQE scores and demonstrated troubleshooting ability of technicians with more than six months experience at the intermediate maintenance level.

H_1: A positive relationship exists between AQE scores and demonstrated troubleshooting ability of technicians with more than six months experience at the intermediate maintenance level.

Since the relationship was predicted as positive, these tests were conducted as one-tailed tests at the .05 level of significance. As indicated in Table 4A, the null hypothesis, H_0, was not rejected for any of the aptitude areas. Although the trend was in the right direction for electronics aptitude, it could not be concluded, from the statistical test and the data, that any of the AQE aptitude scores were positively related to intermediate

TABLE 4A

RELATIONSHIP BETWEEN APTITUDE AND PERFORMANCE: MORE-THAN-SIX-MONTHS-EXPERIENCE-LEVEL GROUP ON INTERMEDIATE MAINTENANCE LEVEL PROBLEMS

Aptitude Cluster	Computed r_s	Computed t	p[a]
General	-.178	- .701	
Administrative	-.333	-1.368	
Mechanical	-.196	- .773	
Electronics	.091	.355	$.70 < p < .80$

Critical t Value = 1.753, $\alpha = .05$, $df = 15$.

[a]Since the null hypothesis would never be rejected with a negative t value in a one-tailed test for positive relationship, all p values are not shown.

maintenance level troubleshooting ability of technicians with more than six months experience.

Analysis of the Correlation of Aptitude Scores with Performance by Type of Troubleshooting Aid

For this analysis, the subjects were again grouped by type of troubleshooting aid so that the three subject groups consisted of 54 subjects using the FPTA, 54 subjects using the LTTA, and 36 subjects using the T.O. The Spearman rank correlation test was used to determine if any positive relationships existed between the four aptitude scores and performance with each type of aid. The AQE

scores for all subjects are contained in Appendix D, Table D-1. The performance indices for each type of aid were taken from Appendix A, Tables A-1, A-2, and A-3. The following is a discussion of the analysis by type of aid.

Correlation of Aptitude Scores and Performance Using the FPTA. The rank ordering of the FPTA performance indices for all 54 subjects and the rank ordering of the four aptitude test scores are contained in Appendix D, Table D-4. The computations of the Spearman r_s and t statistics are contained in Appendix D, Table D-5. The following general hypothesis was tested for each aptitude cluster:

H_0: No positive relationship exists between AQE scores and demonstrated troubleshooting ability of technicians using FPTA documentation.

H_1: A positive relationship exists between AQe scores and demonstrated troubleshooting ability of technicians using FPTA documentation.

These hypothesis tests were conducted as one-tailed tests at the .05 level of significance. Table 4B not only shows that the null hypothesis, H_0, could not be rejected for any of the aptitude clusters, but also that the trend was in the opposite direction from the predicted relationship (i.e., a slight, nonsignificant, negative relationship was found). Therefore, it could not be concluded, at the .05 level of significance, that any of the aptitude scores were positively related to the troubleshooting ability

TABLE 4B

RELATIONSHIP BETWEEN APTITUDE AND PERFORMANCE USING FPTA

Aptitude Cluster	Computed r_s	Computed t	p[a]
General	-.020	- .145	
Administrative	-.172	-1.247	
Mechanical	-.032	- .228	
Electronic	-.217	-1.589	

Critical t Value = 1.678, α = .05, df = 51.

[a]Since the null hypothesis would never be rejected with a negative t value in a one-tailed test for positive relationship, p values are not shown.

of technicians using Fully Proceduralized Troubleshooting Aids.

Correlation of Aptitude Scores and Performance Using the LTTA. The rank ordering for the LTTA performance indices is also contained in Appendix D, Table D-4. The computations of the Spearman r_s and t statistics for the LTTA are shown in Appendix D, Table D-6. The following general hypothesis was tested for each aptitude cluster:

H_0: No positive relationship exists between AQE scores and demonstrated troubleshooting ability of technicians using LTTA documentation.

H_1: A positive relationship exists between AQE scores and demonstrated troubleshooting ability of technicians using LTTA documentation.

These hypothesis tests were conducted as one-tailed tests at the .05 level of significance. Table 4C indicates that the null hypothesis was rejected for only one aptitude cluster--Administrative. Therefore, the data and statistical tests provide evidence that the Administrative aptitude test score is positively related to a technician's performance using the LTTA. For the other three AQE aptitude clusters, relationships, although slight and non-significant, are in the opposite direction from that predicted.

TABLE 4C

RELATIONSHIP BETWEEN APTITUDE AND PERFORMANCE USING THE LTTA

Aptitude Cluster	Computed r_s	Computed t	p[a]
General	-.036	- .254	
Administrative	.277	2.056*	$.02 < p < .05$
Mechanical	-.002	- .013	
Electronics	-.003	- .019	

Critical t Value = 1.678, $\alpha = .05$, $df = 51$.

*Significant at $\alpha = .05$.

[a]Since the null hypothesis would never be rejected with a negative t value in a one-tailed test for positive relationship, all p values are not shown.

Correlation of Aptitude Scores and Performance Using the T.O. The rank ordering of the performance indices for the T.O. and the rank ordering of the subjects' four aptitude test scores are contained in Appendix D, Table D-7. Since the zero-experience subjects were not evaluated using the T.O., this subject group consists of only 36 subjects. Appendix D, Table D-8, contains the computations of the Spearman r_s and t for the T.O. The following general hypothesis was tested for each aptitude cluster:

H_0: No positive relationship exists between AQE scores and demonstrated troubleshooting ability of technicians using T.O. documentation.

H_1: A positive relationship exists between AQE scores and demonstrated troubleshooting ability of technicians using T.O. documentation.

The hypothesis tests were conducted as one-tailed tests at the .05 level of significance. The results of the tests, shown in Table 4D, indicate that, although the trend was in the predicted direction, the null hypothesis, H_0, could not be rejected for any of the four aptitude clusters. Therefore, it could not be concluded that any of the AQE aptitude test scores were positively related to troubleshooting performance of technicians using T.O. documentation.

Limitations of Analysis

The analysis of relationships between the AQE scores and troubleshooting performance must be viewed with

TABLE 4D

RELATIONSHIP BETWEEN APTITUDE AND PERFORMANCE USING THE T.O.

Aptitude Cluster	Computed r_s	Computed t	p
General	.044	.252	$.80 < p < .90$
Administrative	.062	.355	$.70 < p < .80$
Mechanical	.118	.681	$.50 < p < .60$
Electronics	.2410	1.425	$.10 < p < .20$

Critical t Value = 1.693, $\alpha = .05$, $df = 34$.

respect to a major limitation. The subjects which were sampled for the performance data had been placed in this career field based on AQE scores. In particular, a minimum score of 80 was required on the Electronics aptitude cluster. Therefore, the subjects' had already been through a "screening" process based on aptitude scores. Due to this prior screening, the subjects' AQE scores are not representative of the Air Force population as a whole, particularly with respect to Electronics aptitude. The result of the Spearman tests on relationship between aptitude and performance must be viewed with this limitation in mind.

CHAPTER V

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS FOR FUTURE RESEARCH

This chapter summarizes the findings of this research effort, presents the conclusions, and offers some general recommendations for further research. The research findings are presented within the context of the three primary research objectives as presented in Chapter I.

Research Findings

First Research Objective

The first objective of this research was to confirm that there exist individuals who possess native abilities for troubleshooting tasks.

The initial attempt at accomplishing this objective was unsuccessful. It could not be shown through statistical tests of the data that the relative performance of the subjects within each experience-level group was consistent using various types of troubleshooting aids.

In the additional analysis, it was found that the type of troubleshooting aid had a significant effect on performance in the zero-experience group and the six-months-or-less-experience group but not in the more-than-six-months-experience group. And, when the standard times

used for replacement of spare parts was excluded from the performance indices, the more-than-six-months-experience group demonstrated consistency of performance using various types of aids. Additionally, when the subjects' performance was analyzed at the two different maintenance levels, it was again the more-than-six-months-experience group which demonstrated consistency of performance using various types of aids at the intermediate maintenance level.

Second Research Objective

The second research objective was to determine whether personality assessment techniques could be used to identify potential troubleshooting capability prior to actual training and career field assignment.

Originally, it was intended to accomplish this objective by identifying those personality traits which were significantly related to the performance of the subjects in each group. This strategy was based on the belief that the performance of the groups would be significantly different and that the subjects would demonstrate consistency of relative performance using various types of aids.

Although these beliefs were not supported, some insight was gained through additional analysis. First, since the more-than-six-months-experience group did

demonstrate consistency of relative performance using various types of aids at the intermediate maintenance level, a correlation of the performance and the personality test scores of this group was conducted. Responsibility was the only personality trait found to be significantly related to performance in this group.

Secondly, since no significant differences were found among the performance of the different experience-level subject groups, all subjects were placed into one sample group and their performance by type of trouble-shooting aid was correlated with their personality test scores.

No personality traits were found to be significantly related to performance of the subjects using the FPTA or the T.O. The performance of subjects using the LTTA was found to be significantly related to Cautiousness and Emotional Stability.

Third Research Objective

The third and final objective of this research was to confirm the belief that aptitude measures are an accurate indicator of actual troubleshooting performance.

When the performance of the more-than-six-months-experience group was correlated with the AQE scores of that group, it was found that none of the aptitude test scores were significantly related to performance. However,

it was interesting to note that although none of the relationships were significant, the Electronics aptitude cluster was the only one to indicate a positive correlation.

The correlation of aptitude scores with performance by type of troubleshooting aid demonstrated that none of the AQE test scores were significantly related to performance of subjects using the FPTA or the T.O. A significant relationship, however, was found between the Administrative aptitude cluster score and performance of subjects using the LTTA.

Research Conclusions

The following conclusions were drawn from the research findings:

1. Overall, there was little evidence that individuals who perform well using one type of troubleshooting aid, tend to perform well using other types of troubleshooting aids. Thus, it could not be concluded that some individuals possess higher levels of native ability for troubleshooting than do others. The additional analysis which was conducted in an effort to determine if native ability was actually nonexistent, or if it had merely been masked by other factors, revealed that the more-than-six-months-experience group tended to perform consistently using the different types of troubleshooting aids.

Therefore, it is concluded that experience is an important factor in consistency of performance using various types of aids. Thus, it well may be that some individuals actually possess higher levels of native ability for troubleshooting than others, but that these differences do not become evident until the individuals have acquired several months of troubleshooting experience.

2. Although the trend was in the predicted direction (i.e., performance improved as experience increased), differences between the average performances of the three different experience-level groups were not significant. Therefore, it is concluded that the use of more proceduralized aids, such as the FPTA and LTTA, allows technicians with little or no experience to troubleshoot almost as effectively as experienced technicians. With this being the case, then the Air Force should concentrate on developing proceduralized aids which would enable technicians with less training and experience to become productive.

3. There was no evidence that any of the personality traits measured by the Gordon instruments were consistently related to troubleshooting performance. Therefore, the conclusion is that personality testing may not be suitable for selecting personnel for entry into this particular career field. However, since differences in native ability may not be discernable until after individuals have acquired a certain level of experience, the

usefulness of personality testing as a selection device can not be absolutely precluded.

4. No unqualified conclusions can be drawn from the research findings concerning the relationship between aptitude as measured by the AQE and troubleshooting performance. The subjects had already been screened based on AQE scores and, therefore, were not considered to be a representative sample.

Recommendations for Future Research

One area of interest for future research is additional testing for consistency of performance of experienced technicians using various types of aids. If it can be shown that experienced technicians do indeed perform consistently regardless of the type of aid used, then additional analysis can be conducted to determine if the personality trait, Responsibility, is actually related to performance of these technicians. If so, then the presence of the personality trait can be used as a screening factor in selecting of personnel for entry into the career field.

A second recommendation is that additional testing be conducted to determine exactly how little formal training is required to enable technicians to troubleshoot effectively using fully proceduralized aids. This determination must be made in order to adapt current training programs to the use of fully proceduralized aids. It would

also enable the Air Force to better evaluate the potential benefits of using fully proceduralized aids.

Since the samples were considered to be nonrepresentative with respect to AQE scores, no unqualified conclusions could be made concerning the relationship between aptitude test scores and troubleshooting performance. *Therefore, it is recommended that additional research be* conducted in this area using sample groups which have not been screened by the selection procedures based on AQE scores. If it can be shown that aptitude scores, particularly in the Electronics aptitude cluster, definitely are not related to troubleshooting performance with fully proceduralized aids, then the Air Force would have available a larger number of personnel who could be productive as electronics technicians.

APPENDICES

NOTE: Subjects throughout the appendices are numbered in this manner: subjects 1 through 18--Zero Experience; subjects 19 through 36--Less-Than-Six-Months Experience; subjects 37 through 54--More-Than-Six-Months Experience.

APPENDIX A

COMPUTATIONS OF PERFORMANCE INDICES AND FRIEDMAN χ_r^2 STATISTICS

TABLE A-1

PERFORMANCE INDICES: ZERO-EXPERIENCE GROUP

n=18	FPTA			LTTA		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
1	6	235.000	39.167	4	406.533	101.633
2	7	361.730	51.676	4	361.377	90.344
3	7	285.717	40.817	6	205.633	34.272
4	7	209.334	29.905	6	264.900	44.150
5	5	290.850	58.170	4	364.767	91.192
6	6	326.717	54.453	5	245.983	49.197
7	7	193.517	27.645	6	266.333	44.389
8	7	194.066	27.724	5	340.000	68.000
9	7	296.800	42.400	6	241.950	40.325

[a] Total number of problems administered was 7.

[b] Time spent on all 7 problems plus standard times to remove and replace components incorrectly identified as faulty.

[c] $PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time.

n_c = Number of problems solved correctly.

TABLE A-1--Continued

n=18	FPTA			LTTA		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
10	5	279.467	55.893	5	347.183	69.437
11	7	171.200	24.457	5	332.983	66.597
12	7	205.767	29.395	6	221.666	36.944
13	7	224.684	32.098	6	243.017	40.503
14	5	287.233	57.447	5	263.184	52.637
15	7	267.584	38.226	4	407.100	101.775
16	7	234.717	33.531	4	353.483	88.371
17	7	226.650	32.379	5	359.650	71.930
18	6	272.683	45.447	5	275.617	55.123

TABLE A-2

PERFORMANCE INDICES: SIX-MONTHS-OR-LESS-EXPERIENCE GROUP

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
19	3	173.000	57.667	4	142.000	35.500	1	205.000	205.000
20	3	80.000	26.667	3	156.000	52.000	2	380.000	190.000
21	4	103.000	25.750	3	78.000	26.000	4	116.500	29.125
22	4	165.500	41.375	4	155.000	38.875	1	149.000	149.000
23	4	117.400	29.350	3	13.000	4.333	4	118.850	29.713
24	4	132.000	33.000	3	76.500	25.500	4	161.000	40.250
25	4	119.000	29.750	4	101.000	25.250	3	109.000	36.333
26	3	66.600	22.200	3	217.750	72.583	2	353.000	176.500
27	4	116.000	29.000	2	124.000	62.000	1	248.500	248.500

[a] Total number of problems administered was 5.

[b] Time spent on all 5 problems plus standard times to remove and replace components incorrectly identified as faulty.

[c] $PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time.

n_c = Number of problems solved correctly.

TABLE A-2--Continued

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
28	4	124.000	31.000	3	120.000	40.000	2	235.000	117.500
29	3	71.700	23.900	2	205.000	102.500	3	242.967	80.989
30	4	132.000	33.000	3	140.000	46.667	2	154.000	77.000
31	4	136.000	34.000	4	101.000	25.250	3	80.000	26.667
32	3	57.000	19.000	4	78.000	19.500	1	295.000	295.000
33	3	61.000	20.333	4	122.000	30.500	1	154.000	154.000
34	4	126.000	31.500	4	140.000	35.000	1	320.000	320.000
35	2	89.000	44.500	3	117.000	39.000	2	177.067	88.534
36	3	180.271	60.072	3	93.317	21.106	3	184.883	61.628

TABLE A-3

PERFORMANCE INDICES: MORE-THAN-SIX-MONTHS-EXPERIENCE GROUP

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
37	5	113.000	22.600	4	264.017	66.004	2	247.450	123.725
38	5	230.000	46.000	5	103.000	20.600	5	154.000	30.800
39	5	233.300	46.660	5	162.133	32.423	5	110.217	22.043
40	5	204.617	40.923	5	138.083	27.617	5	107.000	21.400
41	5	180.850	36.170	4	163.600	40.900	5	379.800	75.960
42	5	216.833	43.367	3	180.000	60.000	4	164.000	41.000
43	3	268.567	89.522	3	312.000	104.000	2	316.300	158.150
44	5	93.000	18.600	4	182.367	45.592	5	41.000	8.200
45	5	242.467	48.490	5	129.017	25.803	5	139.000	27.800

[a] Total number of problems administered was 5.

[b] Time spent on all 5 problems plus standard times to remove and replace components incorrectly identified as faulty.

[c] $PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time.

n_c = Number of problems solved correctly.

TABLE A-3--Continued

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
46	5	178.300	35.660	5	187.067	37.413	5	152.767	30.553
47	4	159.050	39.763	4	131.417	32.854	4	247.833	61.958
48	5	147.650	29.530	5	128.850	25.770	3	239.917	79.972
49	4	201.183	50.296	5	239.400	47.880	4	261.617	65.404
50	5	167.000	33.400	5	101.633	20.327	5	175.783	35.157
51	5	242.817	48.563	5	331.000	66.200	4	177.000	44.250
52	5	145.417	29.083	4	68.333	17.083	3	254.983	84.994
53	5	81.000	16.200	5	137.000	27.400	5	90.000	18.000
54	5	115.633	23.127	5	178.033	35.607	5	112.000	22.400

TABLE A-4

PERFORMANCE RANKINGS AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS: ZERO-EXPERIENCE GROUP

TYPE OF AID	SUBJECT NUMBER																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
FPTA	10	14	11	5	18	15	2	3	12	16	1	4	6	17	9	8	7	13
LTTA	17	15	1	5	16	7	6	11	3	12	10	2	4	8	18	14	13	9
TOTAL	27	29	12	10	34	22	8	14	15	28	11	6	10	25	27	22	20	22
MEAN	13.5	14.5	6	5	17	11	4	7	7.5	14	5.5	3	5	12.5	13.5	11	10	11

$$\chi_r^2 = \frac{12}{(2)(18)(19)} (7,702) - (3)(2)(19) = 21.123.$$

TABLE A-5

PERFORMANCE RANKING AND FRIEDMAN TWO-WAY ANALYSIS:
SIX-MONTHS-OR-LESS EXPERIENCE

TYPE OF AID	SUBJECT NUMBER																	
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
FPTA	18	4	6	16	8	11	13	2	7	9	3	12	15	1	5	14	10	17
LTTA	15	16	2	12	1	4	7	17	13	10	18	14	6	3	9	8	11	5
T.O.	12	16	3	10	4	5	1.5*	14	15	11	8	7	1.5*	17	18	13	9	6
TOTAL	45	36	11	38	13	20	21.5	33	35	30	29	33	22.5	21	32	35	30	28
MEAN	15	12	3.7	12.6	4.3	6.7	7.2	11	11.7	10	9.7	11	7.5	7	10.7	11.7	10	9.3

$$\chi_r^2 = \frac{12}{(3)(18)(19)} (15,941.5) - (3)(3)(19) = 15.450.$$

*These subjects were tied in performance index and so were assigned the average of the tied ranks.

TABLE A-6

PERFORMANCE RANKINGS AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS: MORE-THAN-SIX-MONTHS-EXPERIENCE GROUP

TYPE OF AID	SUBJECT NUMBER																	
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
FPTA	3	13	14	11	9	12	18	2	16	8	10	6	17	7	15	5	1	4
LTTA	16	3	8	7	12	15	18	13	5	11	9	4	14	2	17	1	6	10
T.O.	17	8	4	3	14	10	18	1	6	7	12	15	13	9	11	16	2	5
TOTAL	36	24	26	21	35	37	54	16	27	26	31	25	44	18	43	22	9	19
MEAN	12	8	8.7	7	11.7	12.3	18	5.3	9	8.7	10.3	8.3	14.7	6	14.3	7.3	3	6.3

$$\chi_r^2 = \frac{12}{(3)(18)(19)} (16,781) - (3)(3)(19) = 25.269.$$

TABLE A-7

PERFORMANCE INDICES RANKINGS FOR FPTA AND LTTA:
ZERO-EXPERIENCE GROUP

Subject Number	FPTA	LTTA
1	1	2
2	1	2
3	2	1
4	1	2
5	1	2
6	2	1
7	1	2
8	1	2
9	2	1
10	1	2
11	1	2
12	1	2
13	1	2
14	2	1
15	1	2
16	1	2
17	1	2
18	1	2
Total	22	32

$$\chi_r^2 = \frac{12}{(18)(2)(3)} (1,508) - (3)(18)(3) = 5.555$$

TABLE A-8

PERFORMANCE INDICES RANKINGS FOR FPTA, LTTA, AND T.O.: SIX-MONTHS-OR-LESS-EXPERIENCE GROUP

Subject Number	FPTA	LTTA	T.O.
19	2	1	3
20	1	2	3
21	2	1	3
22	2	1	3
23	2	1	3
24	2	1	3
25	2	1	3
26	1	2	3
27	1	2	3
28	1	2	3
29	1	3	2
30	1	2	3
21	3	1	2
32	1	2	3
33	1	2	3
34	1	2	3
35	2	1	3
36	2	1	3
Total	28	28	52

$$\chi_r^2 = \frac{12}{(18)(3)(4)} (4,272) - (3)(18)(4) = 21.333$$

TABLE A-9

PERFORMANCE INDICES RANKINGS FOR FPTA, LTTA, AND T.O.: MORE-THAN-SIX-MONTHS-EXPERIENCE GROUP

Subject Number	FPTA	LTTA	T.O.
37	1	2	3
38	3	1	2
39	3	2	1
40	3	2	1
41	1	2	3
42	2	3	1
43	1	2	3
44	2	3	1
45	3	1	2
46	2	3	1
47	2	1	3
48	2	1	3
49	2	1	3
50	2	1	3
51	2	3	1
52	2	1	3
53	1	3	2
54	2	3	1
Total	36	35	37

$$\chi_r^2 = \frac{12}{(18)(3)(4)} (3890) - (3)(18)(4) = .111$$

TABLE A-10

PERFORMANCE INDICES: ZERO-EXPERIENCE GROUP--
WITHOUT SPARE PARTS TIME

n=18	FPTA			LTTA		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
1	6	235.000	39.167	4	326.233	81.558
2	7	286.730	40.961	4	336.380	84.094
3	7	284.717	40.674	6	186.630	31.105
4	7	209.334	29.905	6	247.900	41.316
5	5	290.350	58.070	4	355.267	88.817
6	6	281.717	46.953	5	245.983	49.197
7	7	193.170	27.645	6	263.333	43.888
8	7	192.066	27.438	5	330.000	66.000
9	7	294.800	42.114	6	241.950	40.325

[a] Total number of problems administered was 7.

[b] Time spent on all 7 problems excluding spare parts time.

[c] $PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time excluding spare parts time.

n_c = Number of problems solved correctly.

TABLE A-10--Continued

n=18	FPTA			LTTA		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
10	5	266.467	53.293	5	289.183	57.836
11	7	171.200	24.457	5	329.983	65.996
12	7	192.767	27.538	6	221.666	36.944
13	7	222.684	31.812	6	234.017	39.002
14	5	268.733	53.746	5	260.184	52.037
15	7	259.584	37.083	4	303.100	75.775
16	7	234.707	33.531	4	322.483	80.621
17	7	226.650	32.378	5	348.650	69.730
18	5	243.683	40.614	5	272.617	54.523

TABLE A-11

PERFORMANCE INDICES: SIX-MONTHS-OR-LESS-EXPERIENCE GROUP--
WITHOUT SPARE PARTS TIME

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
19	4	218.000	54.500	5	129.000	25.800	3	212.000	70.667
20	5	111.833	22.377	4	186.000	46.500	3	165.000	55.000
21	5	117.500	23.500	5	89.000	17.800	5	99.000	19.800
22	5	223.000	44.600	5	141.000	28.200	3	188.000	62.667
23	5	136.683	27.337	5	29.500	5.900	5	127.000	25.400
24	5	158.000	31.600	5	104.500	20.900	5	173.000	34.600
25	5	159.000	31.800	5	125.000	25.000	5	91.000	18.200
26	5	116.683	23.334	4	226.500	56.625	3	153.167	51.055
27	5	137.000	27.400	4	145.000	36.250	2	247.000	123.500

[a] Total number of problems administered was 7.

[b] Time spent on all 7 problems excluding spare parts time.

[c] $PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time excluding spare parts time.

n_c = Number of problems solved correctly.

TABLE A-11--Continued

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
28	5	157.000	31.400	4	135.000	33.750	4	152.000	38.000
29	5	115.700	23.140	3	250.000	83.333	4	186.967	46.741
30	5	162.000	32.400	5	192.000	38.400	3	166.000	55.333
31	5	183.000	36.600	5	104.000	20.800	5	121.000	24.200
32	5	88.000	22.000	5	100.000	20.000	2	254.000	127.000
33	5	100.000	20.000	5	165.000	33.000	2	181.000	90.500
34	5	169.000	33.800	5	137.000	27.400	3	173.067	57.688
35	4	127.000	31.750	4	138.000	34.500	3	187.067	62.356
36	4	207.217	51.804	5	113.317	22.663	4	184.383	46.096

TABLE A-12

PERFORMANCE INDICES: MORE-THAN-SIX-MONTHS-EXPERIENCE GROUP--
WITHOUT SPARE PARTS TIME

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
37	5	113.000	22.600	4	232.017	58.004	2	239.450	119.725
38	5	165.000	33.000	5	103.000	20.600	5	104.000	20.800
39	5	214.300	42.860	5	127.133	25.427	5	110.217	22.043
40	5	204.617	40.923	5	137.083	27.417	5	107.000	21.400
41	5	180.850	36.170	4	153.600	32.400	5	139.800	27.960
42	5	216.833	43.367	3	180.000	60.000	4	164.000	41.000
43	3	224.567	74.856	3	297.000	99.000	2	268.300	134.150
44	5	93.000	18.600	4	182.367	45.920	5	33.000	6.600
45	5	122.467	24.493	5	129.017	25.803	5	139.000	27.800

[a] Total number of problems administered was 7.

[b] Time spent on all 7 problems excluding spare parts time.

[c] $PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time excluding spare parts time.

n_c = Number of problems solved correctly.

TABLE A-12--Continued

n=18	FPTA			LTTA			T.O.		
Subject Number	Number Problems Solved[a]	Total Time[b]	Performance Index[c]	Number Problems Solved[a]	Total Time[b]	Performance Index[c]	Number Problems Solved[a]	Total Time[b]	Performance Index[c]
46	5	174.300	34.860	5	157.067	31.413	5	151.767	30.353
47	4	157.050	39.263	4	130.417	32.604	4	177.833	44.458
48	5	147.650	29.530	5	128.850	25.770	3	235.417	78.472
49	4	200.183	50.046	5	239.400	47.880	4	261.617	65.404
50	5	137.000	27.400	5	101.633	20.327	5	175.783	35.157
51	5	233.817	46.763	5	170.000	34.000	4	177.000	44.250
52	5	145.417	29.083	4	60.333	15.083	3	249.983	83.328
53	5	81.000	16.200	5	137.000	27.400	5	58.000	11.600
54	5	115.633	23.127	5	178.033	35.607	5	112.000	22.400

TABLE A-13

PERFORMANCE RANKINGS WITHOUT SPARE PARTS TIME AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS: ZERO-EXPERIENCE GROUP

TYPE OF AID	SUBJECT NUMBER																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
FPTA	10	13	12	5	18	15	4	2	14	16	1	3	6	17	9	8	7	11
LTTA	16	17	1	5	18	7	6	12	4	10	11	2	3	8	14	15	13	9
TOTAL	26	30	13	10	36	22	10	14	18	26	12	5	9	25	23	23	20	20
MEAN	13	15	6.5	5	18	11	5	7	9	13	6	2.5	4.5	12.5	11.5	11.5	10	10

$$\chi_r^2 = \frac{12}{(2)(18)(19)} (7,654) - (3)(2)(19) = 20.281.$$

TABLE A-14

PERFORMANCE RANKINGS WITHOUT SPARE PARTS TIME AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS: SIX-MONTHS-OR-LESS EXPERIENCE GROUP

TYPE OF AID	SUBJECT NUMBER																	
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
FPTA	18	3	5	16	7	10	12	6	8	9	4	13	15	2	1	14	11	17
LTTA	8	16	2	10	1	5	7	17	14	12	18	15	4	3	11	9	13	6
T.O.	15	10	2	14	4	5	1	9	17	6	8	11	3	18	16	12	13	7
TOTAL	41	29	9	40	12	20	20	32	39	27	30	39	22	23	28	35	37	30
MEAN	13.7	9.7	3	13.3	4	6.7	6.7	10.7	13	9	10	13	7.3	7.7	9.3	11.7	12.3	10

$$\chi_r^2 = \frac{12}{(3)(18)(19)} (16,133) - (3)(3)(19) = 17.690.$$

TABLE A-15

PERFORMANCE RANKINGS WITHOUT SPARE PARTS TIME AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS: MORE-THAN-SIX-MONTHS-EXPERIENCE GROUP

TYPE OF AID	SUBJECT NUMBER																	
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
FPTA	3	9	14	13	11	15	18	2	5	10	12	8	17	6	16	7	1	4
LTTA	16	3	4	8	13	17	18	14	6	9	10	5	15	2	11	1	7	12
T.O.	17	3	5	4	8	11	18	1	7	9	13	15	14	10	12	16	2	6
TOTAL	36	15	23	25	32	43	54	17	18	28	35	28	46	18	39	24	10	22
MEAN	12	5	7.7	8.3	10.7	14.3	18	5.7	6	9.3	11.7	9.3	15.3	6	13	8	3.3	7.3

$$\chi_r^2 = \frac{12}{(3)(18)(19)} (16,991) - (3)(3)(19) = 27.725.$$

TABLE A-16

PERFORMANCE INDICES: ZERO-EXPERIENCE GROUP--
ORGANIZATIONAL LEVEL MAINTENANCE

n=18	FPTA			LTTA		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
1	2	71.167	35.584	1	97.800	97.800
2	2	75.030	37.515	2	85.710	42.855
3	2	114.050	57.025	2	27.333	13.665
4	2	73.767	36.884	2	58.567	29.283
5	1	85.600	85.600	2	76.517	38.258
6	2	111.150	55.575	2	53.400	26.700
7	2	59.650	29.825	2	67.383	33.691
8	2	43.733	21.866	2	97.167	48.583
9	2	104.583	52.291	2	36.083	18.041

[a]Total number of organizational level problems administered was 2.

[b]Time spent on all organizational level problems plus standard time to remove and replace components incorrectly identified as faulty.

[c]$PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time.

n_c = Number of problems solved correctly.

TABLE A-16--Continued

n=18	FPTA			LTTA		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
10	2	81.967	40.983	2	139.350	69.675
11	2	53.050	26.525	1	124.833	124.833
12	2	69.117	34.558	2	38.883	19.441
13	2	89.167	44.583	2	59.150	29.575
14	2	60.350	30.175	2	71.567	35.783
15	2	92.717	46.358	2	31.250	15.625
16	2	65.300	32.650	2	55.950	27.975
17	2	57.167	28.583	2	82.000	41.000
18	2	70.350	35.175	2	57.617	28.808

TABLE A-17

PERFORMANCE INDICES: SIX-MONTHS-OR-LESS-EXPERIENCE GROUP--
ORGANIZATIONAL LEVEL MAINTENANCE

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
19	1	45.000	45.000	1	71.000	71.000	2	35.000	17.500
20	2	36.833	18.412	1	42.000	42.000	1	7.000	7.000
21	1	24.500	24.500	2	16.000	8.000	1	7.000	7.000
22	1	61.000	61.000	1	21.000	21.000	2	39.000	19.500
23	1	25.283	25.283	2	16.500	8.250	1	9.000	9.500
24	1	28.000	28.000	2	28.000	14.000	1	15.000	15.000
25	1	40.000	40.000	1	24.000	24.000	2	16.000	8.000
26	2	50.083	25.042	1	45.750	45.750	1	10.167	10.167
27	1	21.000	21.000	2	21.000	10.500	1	9.000	9.000

[a] Total number of organizational level problems administered was 1 or 2.

[b] Time spent on all organizational level problems plus standard time to remove and replace components incorrectly identified as faulty.

[c] $PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time.

n_c = Number of problems solved correctly.

TABLE A-17--Continued

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
28	1	33.000	33.000	1	15.000	15.000	2	20.000	11.000
29	2	45.000	22.500	1	58.000	58.000	1	6.000	6.000
30	1	30.000	30.000	2	52.000	26.000	1	12.000	12.000
31	1	47.000	47.000	1	13.000	13.000	2	42.000	21.000
32	1	31.000	31.000	1	22.000	22.000	1	13.000	13.000
33	2	40.000	20.000	1	43.000	43.000	1	209.000	209.000
34	1	43.000	43.000	1	24.000	24.000	2	18.067	9.033
35	2	38.000	19.000	1	24.000	24.000	1	10.000	10.000
36	1	32.000	32.000	2	10.000	10.000	1	8.000	8.000

TABLE A-18

PERFORMANCE INDICES: MORE-THAN-SIX-MONTHS-EXPERIENCE GROUP--
ORGANIZATIONAL LEVEL MAINTENANCE

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
37	2	47.000	23.500	1	125.000	125.000	1	17.000	17.000
38	1	31.000	31.000	2	24.000	12.000	1	28.000	28.000
39	1	54.000	54.000	1	15.000	15.000	2	5.000	2.500
40	1	46.000	46.000	1	13.000	13.000	2	26.000	13.000
41	1	39.000	39.000	1	16.000	16.000	2	11.000	5.500
42	1	29.000	29.000	2	25.000	12.500	1	26.000	26.000
43	2	59.000	29.500	1	65.000	65.000	1	38.000	38.000
44	2	35.000	17.500	0	60.000	$+\infty$*	1	6.000	6.000

*A score of $+\infty$ was assigned since 0 problems were solved.

[a]Total number of organizational level problems administered was 1 or 2.

[b]Time spent on all organizational level problems plus standard time to remove and replace components incorrectly identified as faulty.

[c]$PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time.

n_c = Number of problems solved correctly.

TABLE A-18--Continued

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
45	1	19.000	19.000	2	28.000	14.000	1	15.000	15.000
46	1	47.000	47.000	1	56.000	56.000	2	10.000	5.000
47	1	19.000	19.000	2	22.000	11.000	1	18.000	18.000
48	1	26.833	26.833	2	34.917	17.458	1	36.417	36.417
49	1	113.000	13.000	1	59.000	59.000	1	25.000	25.000
50	1	71.000	71.000	1	23.000	23.000	2	26.000	13.000
51	1	73.000	73.000	1	10.000	10.000	2	17.000	8.500
52	1	32.000	32.000	2	24.000	12.000	1	36.000	36.000
53	2	39.000	19.500	1	37.000	37.000	1	41.000	41.000
54	2	58.000	29.000	1	46.000	46.000	1	10.000	10.000

TABLE A-19

PERFORMANCE RANKINGS AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS:
ZERO-EXPERIENCE GROUP--ORGANIZATIONAL LEVEL MAINTENANCE

TYPE OF AID	SUBJECT NUMBER																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
FPTA	9	11	17	10	18	16	4	1	15	12	2	7	13	5	14	6	3	8
LTTA	17	14	1	8	12	6	10	15	3	16	18	4	9	11	2	5	13	17
TOTAL	26	25	18	18	30	22	14	16	18	28	20	11	22	16	16	11	16	25
MEAN	13	12.5	9	9	15	11	7	8	9	14	10	5.5	11	8	8	5.5	8	12.5

$$\chi_r^2 = \frac{12}{(2)(18)(19)} (7412) - (3)(2)(19) = 16.035.$$

TABLE A-20

PERFORMANCE RANKINGS AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS:
SIX-MONTHS-OR-LESS-EXPERIENCE GROUP--
ORGANIZATIONAL LEVEL MAINTENANCE

TYPE OF AID	SUBJECT NUMBER																	
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
FPTA	16	1	6	18	8	9	14	7	4	13	5	10	17	11	3	15	2	12
LTTA	18	14	1	8	2	6	11	16	4	7	17	13	5	9	15	11	11	3
T.O.	15	2.5*	2.5*	16	6.5*	14	4.5*	11	6.5*	9.5*	1	12	17	13	18	8	9.5*	4.5*
TOTAL	49	17.5	9.5	42	16.5	29	29.5	34	14.5	29.5	23	35	39	33	36	34	22.5	19.5
MEAN	16.3	5.8	3.2	14	5.5	9.6	9.8	11.3	4.8	9.8	7.7	11.7	13	11	12	11.3	7.5	6.5

$$\chi_r^2 = \frac{12}{(3)(18)(19)} (16,484) - (3)(3)(19) = 21.795.$$

*These subjects were tied in performance index and so were assigned the average of the tied ranks.

TABLE A-21

PERFORMANCE RANKINGS AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS: MORE-THAN-SIX-MONTH-EXPERIENCE GROUP--ORGANIZATIONAL LEVEL MAINTENANCE

TYPE OF AID	SUBJECT NUMBER																	
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
FPTA	7.5*	5	10	15	13	12	7.5*	9	1	2.5*	14	2.5*	6	18	16	17	11	4
LTTA	13	17	3.5*	8	6	9	5	16	18	7	14	2	10	15	11	1	3.5*	12
T.O.	6	10	14	1	7.5*	3	13	17	4	9	2	11	10	12	7.5*	5	15	18
TOTAL	26.5	32	27.5	24	26.5	24	25.5	42	23	18.5	30	15.5	26	45	34.5	23	29.5	34
MEAN	8.8	10.7	9.1	8	8.8	8	8.5	14	7.7	6.2	10	5.2	8.7	15	11.5	7.7	9.8	11.3

$$\chi_r^2 = \frac{12}{(3)(18)(19)} (15,209) - (3)(3)(19) = 6.833.$$

*These subjects were tied in performance index and so were assigned the average of the tied ranks.

TABLE A-22

PERFORMANCE INDICES: ZERO-EXPERIENCE GROUP--
INTERMEDIATE LEVEL MAINTENANCE

n=18	FPTA			LTTA		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
1	4	163.833	40.958	3	308.733	102.911
2	5	286.700	57.340	2	275.667	137.834
3	5	171.667	34.333	4	178.300	44.575
4	5	135.567	27.113	4	206.333	51.583
5	4	205.250	51.313	2	288.250	144.125
6	4	215.567	53.892	3	192.583	64.194
7	5	133.867	26.773	4	198.950	49.738
8	5	150.333	30.063	3	242.833	80.944
9	5	192.217	38.443	4	205.867	51.467

[a]Total number of intermediate level problems administered was 5.

[b]Time spent on all intermediate level problems plus standard time to remove and replace components incorrectly identified as faulty.

[c]$PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time.

n_c = Number of problems solved correctly.

TABLE A22--Continued

n=18	FPTA			LTTA		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
10	3	197.500	65.833	3	207.833	69.278
11	5	118.150	23.630	4	210.150	52.538
12	5	136.650	27.330	4	182.783	45.696
13	5	135.517	27.103	4	183.867	45.967
14	3	226.883	75.628	3	191.617	63.873
15	5	174.867	34.973	2	375.850	187.925
16	5	169.417	33.883	2	297.533	148.767
17	5	169.483	33.897	3	277.650	92.550
18	4	202.333	50.583	3	218.000	72.667

TABLE A-23

PERFORMANCE RANKINGS AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS: SIX-MONTH-OR-LESS EXPERIENCE GROUP--INTERMEDIATE LEVEL MAINTENANCE

TYPE OF AID	SUBJECT NUMBER																	
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
FPTA	17	6	5	15	8	12.5*	9	3	7	10	4	12.5*	14	1	2	11	16	18
LTTA	10	15	6	11	1	5	3.5*	17	16	13	18	14	3.5*	2	7	9	12	8
T.O.	15	14	2	12	3	5	4	11	16	10	8	7	1	17	13	18	9	6
TOTAL	42	35	13	38	12	22.5	16.5	31	39	33	30	33.5	18.5	20	22	38	37	32
MEAN	14	11.7	4.3	12.7	4	7.5	5.5	10.3	13	11	10	10.2	6.2	6.7	7.3	12.7	12.3	10.7

$$\chi_r^2 = \frac{12}{(3)(18)(19)} (16,181) - (3)(3)(19) = 18.251.$$

*These subjects were tied in performance index and so were assigned the average of the tied ranks.

TABLE A-24

PERFORMANCE INDICES: MORE-THAN-SIX-MONTHS-EXPERIENCE GROUP--
INTERMEDIATE LEVEL MAINTENANCE

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
37	3	66.000	22.000	3	139.017	46.339	1	230.450	230.450
38	4	199.000	49.750	3	79.000	26.333	4	126.000	31.500
39	4	179.300	44.825	4	147.133	36.783	3	105.217	35.072
40	4	158.617	39.654	4	125.083	31.271	3	81.000	27.000
41	4	141.850	35.463	3	147.600	49.200	3	368.800	122.933
42	4	187.833	46.958	1	155.000	155.000	3	138.000	46.000
43	1	209.567	209.567	2	247.000	123.500	1	278.300	278.300
44	3	58.000	19.333	4	122.367	30.592	4	35.000	8.750
45	4	223.467	55.867	3	101.017	33.672	4	124.000	31.000

[a] Total number of intermediate level problems administered was 5.

[b] Time spent on all intermediate level problems plus standard time to remove and replace components incorrectly identified as faulty.

[c] $PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time.

n_c = Number of problems solved correctly.

TABLE A-24--Continued

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
46	4	131.300	32.825	4	131.067	32.767	3	142.767	47.589
47	3	140.050	46.683	2	109.417	54.709	3	229.833	76.611
48	4	120.817	30.204	3	93.933	31.311	2	203.500	101.750
49	3	88.183	29.394	4	180.400	45.111	3	236.617	78.872
50	4	96.000	24.000	4	78.633	19.658	3	149.783	49.928
51	4	169.817	42.454	4	321.000	80.250	2	160.000	80.000
52	4	113.417	28.354	2	44.333	22.167	2	218.783	109.492
53	3	42.000	14.000	4	100.000	25.000	4	49.000	12.250
54	3	57.633	19.211	4	132.033	33.008	4	102.000	25.500

TABLE A-25

PERFORMANCE RANKINGS AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS:
ZERO-EXPERIENCE GROUP--INTERMEDIATE LEVEL MAINTENANCE

TYPE OF AID	SUBJECT NUMBER																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
FPTA	12	16	9	4	14	15	2	6	11	17	1	5	3	18	10	7	8	13
LTTA	14	15	1	6	16	9	4	12	5	10	7	2	3	8	18	17	13	11
TOTAL	26	31	10	10	30	24	6	18	16	27	8	7	6	26	28	24	21	24
MEAN	13	15.5	5	5	15	12	3	9	8	13.5	4	3.5	3	13	14	12	10.5	12

$$\chi_r^2 = \frac{12}{(2)(18)(19)} (7,860) - (3)(2)(19) = 23.895.$$

TABLE A-26

PERFORMANCE INDICES: SIX-MONTHS-OR-LESS-EXPERIENCE GROUP--
INTERMEDIATE LEVEL MAINTENANCE

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
19	4	218.000	54.500	5	213.000	42.600	2	247.450	123.725
20	5	116.833	23.367	4	198.000	49.500	5	154.000	30.800
21	5	127.500	25.500	5	94.000	18.800	5	110.217	22.043
22	5	226.300	45.260	5	176.500	35.300	5	107.000	21.400
23	5	142.683	28.537	5	29.500	5.900	5	379.800	75.960
24	5	160.000	32.000	5	104.500	20.900	4	164.000	41.000
25	5	166.000	33.200	5	125.000	25.000	2	316.300	158.150
26	5	116.683	23.337	4	263.500	65.875	5	41.000	8.200
27	5	137.000	27.400	4	145.000	36.250	5	139.000	27.800

[a] Total number of intermediate level problems administered was 5.

[b] Time spent on all intermediate level problems plus standard time to remove and replace components incorrectly identified as faulty.

[c] $PI = \frac{\Sigma T}{n_c}$; $n_c \geq 1$.

PI = Performance index.

T = Total time.

n_c = Number of problems solved correctly.

TABLE A-26--Continued

n=18	FPTA			LTTA			T.O.		
Subject Number	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index	Number[a] Problems Solved	Total[b] Time	Performance[c] Index
28	5	157.000	31.400	4	135.000	33.750	5	152.767	30.553
29	5	116.700	23.340	3	236.000	87.667	4	247.833	61.958
30	5	162.000	32.400	5	192.000	38.400	3	239.917	79.972
31	5	183.000	36.600	5	114.000	22.800	4	261.617	65.404
32	4	88.000	22.000	5	100.000	20.000	5	175.783	35.157
33	5	101.000	20.200	5	165.000	33.000	4	177.000	44.250
34	5	169.000	33.800	5	164.000	32.800	3	254.983	84.994
35	4	127.000	31.750	4	141.000	35.250	5	90.000	18.000
36	4	212.217	53.054	5	113.317	22.663	5	112.000	22.400

TABLE A-27

PERFORMANCE RANKINGS AND FRIEDMAN TWO-WAY ANALYSIS OF VARIANCE TEST RESULTS
MORE-THAN-SIX-MONTHS-EXPERIENCE GROUP--
INTERMEDIATE LEVEL MAINTENANCE

TYPE OF AID	SUBJECT NUMBER																	
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
FPTA	4	16	13	11	10	15	18	3	17	9	14	8	7	5	12	6	1	2
LTTA	13	4	11	6	14	18	17	5	10	8	15	7	12	1	16	2	3	9
T.O.	17	6	7	4	16	8	18	1	5	9	11	14	12	10	13	15	2	3
TOTAL	34	26	31	21	40	41	53	9	32	26	40	29	31	16	41	23	6	14
MEAN	11.3	8.6	10.3	7	13.3	13.7	17.7	3	10.6	8.7	13.3	9.7	10.3	5.3	13.7	7.7	2	4.7

$$\chi_r^2 = \frac{12}{(3)(18)(19)} (17,205) - (3)(3)(19) = 30.228.$$

APPENDIX B

DIFFERENCE IN PERFORMANCE BETWEEN DIFFERENT EXPERIENCE-LEVEL GROUPS

TABLE B-1

AVERAGE PERFORMANCE INDICES: ZERO-EXPERIENCE GROUP

Subject Number	FPTA[a] PI	LTTA[b] PI	API[c] API
1	39.167	101.633	70.400
2	51.676	90.344	71.010
3	40.817	34.272	37.545
4	29.905	44.150	37.028
5	58.170	91.192	74.681
6	54.453	49.197	51.825
7	27.645	44.389	36.017
8	27.724	68.000	47.862
9	42.400	40.325	41.363
10	55.893	69.437	62.665
11	24.457	66.597	45.527
12	29.395	36.944	33.170
13	32.098	40.503	36.301
14	57.447	52.637	55.042
15	38.226	101.775	70.001
16	33.531	88.371	60.951
17	32.379	71.930	52.155
18	45.447	55.123	50.285

[a]Performance index with spare parts time for FPTA.

[b]Performance index with spare parts time for LTTA.

[c]Average Performance Index = $\frac{\text{FPTA} + \text{LTTA}}{2}$.

TABLE B-2

AVERAGE PERFORMANCE INDICES:
SIX-MONTHS-OR-LESS-EXPERIENCE GROUP

	FPTA	LTTA	T.O.	API
Subject Number	PI[a]	PI[b]	PI[c]	API[d]
19	54.500	42.600	80.000	59.033
20	23.367	49.500	129.000	67.289
21	25.500	18.800	24.700	23.000
22	45.260	35.300	62.667	47.742
23	28.537	5.900	25.570	20.002
24	32.000	20.900	35.200	29.367
25	33.200	25.000	24.400	27.533
26	23.337	65.875	121.056	69.756
27	27.400	36.250	128.750	64.133
28	31.400	33.750	64.250	43.133
29	23.334	87.667	62.242	57.750
30	32.400	38.400	55.333	42.044
31	36.600	22.800	24.400	27.933
32	22.000	20.000	154.000	65.333
33	20.200	33.000	181.500	78.233
34	33.800	32.800	112.689	59.763
35	31.750	35.250	62.356	43.119
36	53.054	22.663	48.221	41.313

[a]Performance index with spare parts time for FPTA.

[b]Performance Index with spare parts time for LTTA.

[c]Performance index with spare parts time for T.O.

[d]Average Performance Index = $\frac{\text{FPTA + LTTA + T.O.}}{3}$.

TABLE B-3

AVERAGE PERFORMANCE INDICES:
MORE-THAN-SIX-MONTHS-EXPERIENCE GROUP

Subject Number	FPTA	LTTA	T.O.	API
	PI[a]	PI[b]	PI[c]	API[d]
37	22.600	66.004	123.725	70.776
38	46.000	20.600	30.800	32.467
39	46.660	32.423	22.043	33.709
40	40.923	27.617	21.400	29.980
41	36.170	40.900	75.960	51.010
42	43.367	60.000	41.000	48.122
43	89.522	104.000	158.150	117.224
44	18.600	45.492	8.200	24.131
45	48.490	25.803	27.800	34.031
46	35.660	37.413	30.553	34.542
47	39.763	32.854	61.958	44.858
48	29.530	25.770	79.972	45.091
49	50.296	47.880	65.404	54.527
50	33.400	20.327	35.157	29.628
51	48.563	66.200	44.250	53.004
52	29.083	17.083	84.994	43.720
53	16.200	27.400	18.000	20.533
54	23.127	35.607	22.400	19.578

[a]Performance index with spare parts time for FPTA.

[b]Performance index with spare parts time for LTTA.

[c]Performance index with spare parts time for T.O.

[d]Average Performance Index = $\frac{\text{FPTA + LTTA + T.O.}}{3}$.

TABLE B-4

PERFORMANCE RANKINGS AND KRUSKAL-WALLIS COMPUTATIONS

Zero-Experience Group		Six-Months-or-Less Group		More-Than-Six-Months Group	
Subject Number	Rank	Subject Number	Rank	Subject Number	Rank
1	49	19	40	37	50
2	51	20	46	38	11
3	19	21	4	39	13
4	18	22	29	40	10
5	52	23	2	41	33
6	34	24	8	42	31
7	16	25	7	43	54
8	30	26	47	44	5
9	21	27	44	45	14
10	43	28	24	46	15
11	28	29	39	47	26
12	12	30	22	48	27
13	17	31	6	49	37
14	38	32	45	50	9
15	48	33	53	51	36
16	42	34	41	52	25
17	35	35	23	53	3
18	32	36	20	54	1
$R_1 = 585$		$R_2 = 500$		$R_3 = 400$	

$$H = \frac{12}{(54)(55)} \left(\frac{585^2}{18} + \frac{500^2}{18} + \frac{400^2}{18}\right) - 3(55) = 3.850$$

APPENDIX C

SPEARMAN RANK CORRELATION COEFFICIENT: GORDON PERSONALITY TRAIT SCORES WITH PERFORMANCE INDICES

TABLE C-1

AVERAGE PERFORMANCE INDICES: MORE-THAN-SIX-MONTHS GROUP--
INTERMEDIATE LEVEL MAINTENANCE

Subject Number	FPTA PI[a]	LTTA PI	T.O. PI	API[b] API
37	22.000	46.339	230.450	99.596
38	49.750	26.333	31.500	35.861
39	44.825	36.783	35.072	38.893
40	39.654	31.271	27.000	32.642
41	35.463	49.200	122.933	69.199
42	46.958	155.000	46.000	82.653
43	209.567	123.500	278.300	203.789
44	19.333	30.592	8.750	19.558
45	55.867	33.672	31.000	40.180
46	32.825	32.767	47.589	37.727
47	46.683	54.709	76.611	59.334
48	30.204	31.311	101.750	54.422
49	29.394	45.111	78.872	51.122
50	24.000	19.658	49.928	31.195
51	42.454	80.250	80.000	67.568
52	28.354	22.167	109.492	53.338
53	14.000	25.000	12.250	17.083
54	19.211	33.008	25.500	25,900

[a]Performance index.

[b]Average performance index = $\frac{\text{FPTA + LTTA + T.O.}}{3}$

TABLE C-2

GORDON PERSONALITY SCORES

Personality Traits	Subject Number								
	1	2	3	4	5	6	7	8	9
Cautiousness	29	26	27	28	1	18	21	14	24
Ascendancy	23	18	24	23	22	17	11	14	24
Vigor	27	20	26	20	18	21	28	15	25
Personal Relations	29	24	30	32	16	16	19	17	24
Sociability	21	12	22	23	24	18	10	14	26
Original Thinking	32	22	25	34	14	18	22	18	34
Emotional Stability	30	28	26	32	22	32	22	15	23
Responsibility	32	25	26	25	16	29	27	14	27

Personality Traits	Subject Number								
	10*	11	12	13	14	15	16	17	18
Cautiousness	-	23	19	23	29	28	29	20	26
Ascendancy	-	23	27	24	20	19	10	20	24
Vigor	-	30	31	22	21	36	15	20	24
Personal Relations	-	19	20	21	31	20	30	31	29
Sociability	-	19	17	19	22	17	21	21	26
Original Thinking	-	22	30	30	35	28	20	29	19
Emotional Stability	-	20	28	22	26	32	20	22	27
Responsibility	-	21	20	21	31	31	22	25	27

*Subject 10 did not have Gordon Personality Test scores.

TABLE C-2--Continued

Personality Traits	Subject Number								
	19	20	21	22	23	24	25	26	27
Cautiousness	22	22	33	27	30	25	30	18	20
Ascendancy	25	20	25	25	11	20	16	17	25
Vigor	26	25	33	31	16	17	23	18	22
Personal Relations	26	25	19	28	27	35	19	19	34
Sociability	19	18	16	24	10	20	9	18	32
Original Thinking	23	24	27	34	19	17	22	19	32
Emotional Stability	29	25	27	26	26	30	27	18	20
Responsibility	20	23	30	33	24	25	23	18	23

Personality Traits	Subject Number								
	28	29	30	31	32	33	34	35	36
Cautiousness	29	30	31	32	22	23	23	29	34
Ascendancy	20	25	28	22	26	26	11	21	9
Vigor	19	26	31	25	31	25	18	22	29
Personal Relations	26	18	24	25	26	26	14	23	20
Sociability	20	24	22	20	23	20	8	18	14
Original Thinking	17	20	26	36	33	32	19	33	25
Emotional Stability	27	27	30	32	34	32	25	33	22
Responsibility	25	25	28	29	25	30	20	32	27

TABLE C-2--Continued

Personality Traits	Subject Number								
	37	38	39	40	41	42	43	44	45
Cautiousness	28	17	28	28	22	30	30	18	24
Ascendancy	8	15	13	24	14	10	13	7	27
Vigor	25	27	21	24	26	17	12	13	32
Personal Relations	24	19	22	34	23	19	25	14	17
Sociability	15	14	13	18	14	15	14	13	19
Original Thinking	19	24	22	32	23	11	23	11	35
Emotional Stability	21	11	25	34	19	27	24	14	27
Responsibility	24	20	30	32	19	22	15	26	28

Personality Traits	Subject Number								
	46	47	48	49	50	51	52	53	54
Cautiousness	33	31	37	17	34	22	33	29	34
Ascendancy	23	19	19	31	20	29	25	24	19
Vigor	19	19	22	27	18	33	22	31	29
Personal Relations	26	29	35	32	18	24	33	17	26
Sociability	21	19	20	31	20	35	20	16	19
Original Thinking	22	27	24	26	15	30	24	33	23
Emotional Stability	29	34	35	22	32	13	33	32	26
Responsibility	27	28	34	22	24	20	29	30	34

TABLE C-3

SPEARMAN RANK ORDERING--API AND GORDON TRAITS--
INTERMEDIATE LEVEL MAINTENANCE: MORE-THAN-SIX-MONTHS GROUP

API and Personality Traits	Subject Number								
	37	38	39	40	41	42	43	44	45
API[a]	17	6	8	5	15	16	18	2	9
Cautiousness	11	17.5	11	11	15.4	7.5	7.5	16	13
Ascendancy	17	12	14.5	5.5	13	16	14.5	18	3
Vigor	8	5.5	12	9	7	16	18	17	2
Personal Relations	9.5	13.5	12	2	11	13.5	8	18	16.5
Sociability	12.5	15	17.5	10	15	12.5	15	17.5	8
Original Thinking	15	8	13.5	3	11	17.5	11	17.5	1
Emotional Stability	14	18	11	2.5	15	8.5	12	16	8.5
Responsibility	11.5	15.5	4.5	3	17	13.5	18	10	7.5

[a]Average Performance Index ranked 1 to 18 for the more than six months group.

TABLE C-3--Continued

API and Personality Traits	Subject Number								
	46	47	48	49	50	51	52	53	54
API[a]	7	13	12	10	4	14	11	1	3
Cautiousness	4.5	6	1	17.5	2.5	14.5	4.5	9	2.5
Ascendancy	7	10	10	1	8	2	4	5.5	10
Vigor	13.5	13.5	10.5	5.5	15	1	10.5	3	4
Personal Relations	6.5	5	1	4	15	9.5	3	16.5	6.5
Sociability	3	8	5	2	5	1	5	11	8
Original Thinking	13.5	5	8	6	16	4	8	2	11
Emotional Stability	7	2.5	1	13	5.5	17	4	5.5	10
Responsibility	9	7.5	1.5	13.5	11.5	15.5	6	4.5	1.5

[a]Average Performance Index ranked 1 to 18 for the more-than-six-months group.

TABLE C-4

SPEARMAN RANK CORRELATION--API WITH GORDON PERSONALITY TRAITS--
INTERMEDIATE LEVEL MAINTENANCE: MORE-THAN-SIX-MONTHS GROUP

Cautiousness

$$r_s = \frac{484.5 + 479.75 - 949.5}{2\sqrt{(484.5)(479.75)}} = .016$$

$$t = .01\sqrt{\frac{18 - 2}{1 - (.0155)^2}} = .062$$

Ascendancy

$$r_s = \frac{481.5 + 484.5 - 759}{2\sqrt{(481.5)(484.5)}} = .214$$

$$t = .214\sqrt{\frac{18 - 2}{1 - (.2143)^2}} = .878$$

Vigor

$$r_s = \frac{482.5 + 484.5 - 811.5}{2\sqrt{(482.5)(484.5)}} = .161$$

$$t = .161\sqrt{\frac{18 - 2}{1 - (.1608)^2}} = .652$$

Personal Relations

$$r_s = \frac{484.5 + 482.5 - 1,251}{2\sqrt{(484.5)(482.5)}} = -.294$$

$$t = -.294\sqrt{\frac{18 - 2}{1 - (-.2937)^2}} = -1.229$$

TABLE C-4--Continued

Sociability

$$r_s = \frac{484.5 + 477.5 - 964}{2\sqrt{(484.5)(477.5)}} = -.002$$

$$t = -.002\sqrt{\frac{18 - 2}{1 - (-.0021)^2}} = -.008$$

Original Thinking

$$r_s = \frac{484.5 + 479.5 - 870}{2\sqrt{(484.5)(479.5)}} = .098$$

$$t = .098\sqrt{\frac{18 - 2}{1 - (.0975)^2}} = .392$$

Emotional Stability

$$r_s = \frac{484.5 + 483.0 - 826.5}{2\sqrt{(484.5)(483.0)}} = .146$$

$$t = .146\sqrt{\frac{18 - 2}{1 - (.1457)^2}} = .589$$

Responsibility

$$r_s = \frac{484.5 + 481.5 - 468}{2\sqrt{(484.5)(481.5)}} = .516$$

$$t = .5155\sqrt{\frac{18 - 2}{1 - (.5155)^2}} = 2.407^*$$

*Significant at $\alpha = .05$.

TABLE C-5

SPEARMAN RANK ORDERING--FPTA/LTTA AND PERSONALITY TEST SCORES

FPTA/LTTA and Personality Traits	Subject Number								
	1	2	3	4	5	6	7	8	9
FPTA	34	47	36	19	52	49	13	14	38
LTTA	51	49	20	32	50	36	33	45	28
Cautiousness	18.5	29.5	27.5	24	53	48	43	52	32.5
Ascendancy	21.5	37	16.5	21.5	24.5	38.5	47	42.5	16.5
Vigor	15	18	18.5	38	44.5	35	13	50.5	23
Personal Relations	13	28	10.5	6.5	50.5	50.5	41	48	28
Sociability	15.5	49	12	9.5	7	33	50.5	44	4.5
Original Thinking	11.5	35.5	23.5	5	51	46.5	35.5	46.5	5
Emotional Stability	14	18.5	29	9	40.5	9	40.5	50	37
Responsibility	5	30	25.5	30	51	15	22	53	22

TABLE C-5--Continued

FPTA/LTTA and Personality Traits	Subject Number								
	10*	11	12	13	14	15	16	17	18
FPTA	-	10	17	23	51	33	28	24	41
LTTA	-	44	25	29	38	52	48	46	39
Cautiousness	-	35.5	46	35.5	18.5	24	18.5	44.5	29.5
Ascendancy	-	21.5	4.5	16.5	29.5	34.5	49.5	29.5	16.5
Vigor	-	10	7	31	35	1	50.5	38	26.5
Personal Relations	-	41	36	34	8.5	36	10.5	8.5	13
Sociability	-	27.5	36.5	27.5	12	36.5	15.5	15.5	4.5
Original Thinking	-	35.5	15	15	2.5	18	39.5	17	43
Emotional Stability	-	46	18.5	40.5	29	9	46	40.5	23
Responsibility	-	43.5	46.5	43.5	7.5	7.5	41	30	22

*Subject 10 had no Gordon Personality Test scores.

TABLE C-5--Continued

FPTA/LTTA and Personality Traits	Subject Number								
	19	20	21	22	23	24	25	26	27
FPTA	50	9	11	40	15	22	26	7	12
LTTA	31	37	2	22	1	7	10	41	24
Cautiousness	40	40	6	27.5	13	31	13	48	44.5
Ascendancy	10.5	29.5	10.5	10.5	47	29.5	40	38.5	10.5
Vigor	18.5	23	2.5	7	49	47.5	28	44.5	31
Personal Relations	19.5	24	41	15	16	1.5	41	41	3.5
Sociability	27.5	33	38.5	7	50.5	21	52	33	2
Original Thinking	30.5	26.5	19.5	5	43	48.5	35.5	43	11.5
Emotional Stability	16.5	33	23	29	29	14	23	49	46
Responsibility	11	38	11	3	35	30	38	50	38

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A STUDY OF THE IMPACT OF PERSONALITY DIFFERENCES ON TROUBLESHOO--ETC(U)
JUN 77 F HERNANDEZ, T T COCO, J L HAMM

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TABLE C-5--Continued

FPTA/LTTA and Personality Traits	Subject Number								
	28	29	30	31	32	33	34	35	36
FPTA	20	8	25	32	4	3	29	21	48
LTTA	19	47	27	9	4	18	16	21	8
Cautiousness	18.5	13	9.5	8	40	35.5	35.5	18.5	3
Ascendancy	29.5	10.5	3	24.5	6.5	6.5	47	26	51
Vigor	41	18.5	7	23	7	23	44.5	31	11.5
Personal Relations	19.5	45.5	28	24	19.5	19.5	52.5	31.5	36
Sociability	21	7	12	21	9.5	21	53	33	44
Original Thinking	48.5	39.5	21.5	1	8	11.5	43	8	23.5
Emotional Stability	23	23	14	9	35.5	9	33	4.5	40.5
Responsibility	30	30	18	15	30	11	46.5	5	22

TABLE C-5--Continued

FPTA/LTTA and Personality Traits	Subject Number								
	37	38	39	40	41	42	43	44	45
FPTA	5	42	43	37	31	39	53	2	44
LTTA	42	6	15	14	30	40	53	34	12
Cautiousness	24	50.5	24	24	40	13	13	48	32.5
Ascendancy	52	41	44.5	16.5	42.5	49.5	44.5	53	4.5
Vigor	23	15	35	26.5	18.5	47.5	53	52	4
Personal Relations	28	41	33	3.5	31.5	41	24	52.5	48
Sociability	40.5	44	47.5	33	44	40.5	44	47.5	27.5
Original Thinking	43	26.5	35.5	11.5	30.5	52.5	30.5	52.5	2.5
Emotional Stability	44	53	33	2.5	48	23	35.5	51	23
Responsibility	35	46.5	11	5	49	41	52	25.5	18

TABLE C-5--Continued

FPTA/LTTA and Personality Traits	Subject Number								
	46	47	48	49	50	51	52	53	54
FPTA	30	35	18	46	27	45	16	1	6
LTTA	26	17	11	35	5	43	2	13	23
Cautiousness	6	9.5	12	50.5	3	40	6	18.5	3
Ascendancy	21.5	34.5	34.5	1	29.5	2	10.5	16.5	34.5
Vigor	41	41	31	15	44.5	2.5	31	7	11.5
Personal Relations	19.5	13	1.5	6.5	45.5	28	5	48	19.5
Sociability	15.5	27.5	21	3	21	1	21	38.5	27.5
Original Thinking	35.5	19.5	26.5	21.5	50	15	26.5	8	30.5
Emotional Stability	16.5	2.5	1	40.5	9	52	4.5	9	29
Responsibility	22	18	1.5	41	35	46.5	15	11	1.5

TABLE C-6

SPEARMAN RANK CORRELATION[a]--FPTA WITH GORDON TRAITS

Cautiousness

$$r_s = \frac{12,402 + 12,340.5 - 24,070.5}{2\sqrt{(12,402)(12,340.5)}} = .027$$

$$t = .027\sqrt{\frac{53 - 2}{1 - (.027)^2}} = .194$$

Ascendancy

$$r_s = \frac{12,402 + 12,334 - 24,379}{2\sqrt{(12,402)(12,334)}} = .014$$

$$t = .014\sqrt{\frac{53 - 2}{1 - (.014)^2}} = .103$$

Vigor

$$r_s = \frac{12,402 + 12,351.5 - 23,486.5}{2\sqrt{(12,402)(12,351.5)}} = .051$$

$$t = .051\sqrt{\frac{53 - 2}{1 = (.051)^2}} = .366$$

Personal Relations

$$r_s = \frac{12,402 + 12,334 - 26,329}{2\sqrt{(12,402)(12,334)}} = -.064$$

$$t = -.064\sqrt{\frac{53 - 2}{1 - (-.064)^2}} = -.461$$

[a]Spearman Rank Order Correlation FPTA Performance Index ranked 1 to 53 with Gordon Personality Trait Scores ranked 1 to 53.

TABLE C-6--Continued

Sociability

$$r_s = \frac{12,402 + 12,324 - 27,431}{2\sqrt{(12,402)(12,310)}} = -.109$$

$$t = -.109\sqrt{\frac{53 - 2}{1 - (-.109)^2}} = -.786$$

Original Thinking

$$r_s = \frac{12,402 + 12,349.5 - 26,301.5}{2\sqrt{(12,402)(12,349.5)}} = -.063$$

$$t = -.063\sqrt{\frac{53 - 2}{1 - (-.063)^2}} = -.448$$

Emotional Stability

$$r_s = \frac{12,402 + 12,310 - 25,422}{2\sqrt{(12,402)(12,310)}} = -.029$$

$$t = -.028\sqrt{\frac{53 - 2}{1 - (-.029)^2}} = -.205$$

Responsibility

$$r_s = \frac{12,402 + 12,335 - 25,025}{2\sqrt{(12,402)(12,335)}} = -.012$$

$$t = -.012\sqrt{\frac{53 - 2}{1 (-.012)^2}} = -.083$$

TABLE C-7

SPEARMAN RANK ORDER CORRELATION[a]--LTTA WITH GORDON TRAITS

Cautiousness

$$r_s = \frac{12,402 + 12,340.5 - 16,122.5}{2\sqrt{(12,402)(12,340.5)}} = .348$$

$$t = .348\sqrt{\frac{53 - 2}{1 - (.348)^2}} = 2.654^*$$

Ascendancy

$$r_s = \frac{12,339 + 12,402 - 21,488}{2\sqrt{(12,339)(12,402)}} = .131$$

$$t = .131\sqrt{\frac{53 - 2}{1 - (.131)^2}} = .947$$

Vigor

$$r_s = \frac{12,402 + 12,352 - 20,531.75}{2\sqrt{(12,402)(12,352)}} = .171$$

$$t = .171\sqrt{\frac{53 - 2}{1 - (.171)^2}} = 1.236$$

Personal Relations

$$r_s = \frac{12,402 + 12,351.5 - 22,163.75}{2\sqrt{(12,402)(12,351.5)}} = .105$$

$$t = .105\sqrt{\frac{53 - 2}{1 - (.105)^2}} = .751$$

[a]Spearman Rank Order Correlation LTTA Performance Index ranked 1 to 53 with Gordon Personality Trait Scores ranked 1 to 53.

*Significant at $\alpha = .05$.

TABLE C-7--Continued

Sociability

$$r_s = \frac{12,402 + 12,324 - 28,109}{2\sqrt{(12,402)(12,324)}} = -.137$$

$$t = -.137\sqrt{\frac{53 - 2}{1 - (-.137)^2}} = -.986$$

Original Thinking

$$r_s = \frac{12,402 + 12,346 - 20,046.5}{2\sqrt{(12,402)(12,346)}} = .190$$

$$t = .190\sqrt{\frac{53 - 2}{1 - (.190)^2}} = 1.382$$

Emotional Stability

$$r_s = \frac{12,402 + 12,312 - 16,531}{2\sqrt{(12,402)(12,312)}} = .331$$

$$t = .331\sqrt{\frac{53 - 2}{1 - (.331)^2}} = 2.506$$

Responsibility

$$r_s = \frac{12,402 + 12,335 - 19,532}{2\sqrt{(12,402)(12,335)}} = .211$$

$$t = .2104\sqrt{\frac{53 - 2}{1 - (.211)^2}} = 1.537$$

TABLE C-8

SPEARMAN RANK ORDERING--T.O. AND GORDON PERSONALITY TEST SCORES

T.O. and Personality Traits	Subject Number								
	19	20	21	22	23	24	25	26	27
T.O.	27	33	8	22	9	14	6.5	30	32
Cautiousness	29	29	6	22	13	23	13	33.5	32
Ascendancy	9.5	19.5	9.5	9.5	31.5	19.5	26	25	9.5
Vigor	13	16.5	1.5	5.5	34	32.5	20	30	22.5
Personal Relations	12.5	17	28	8	9	1.5	28	28	3.5
Sociability	17.5	21.5	24.5	4.5	34	12	35	21.5	2
Original Thinking	21.5	17.5	11.5	3	29.5	32.5	25	29.5	8
Emotional Stability	12.5	24	16.5	21	21	10.5	16.5	33	31
Responsibility	8	27	8	3	24	20.5	27	35	27

TABLE C-8--Continued

T.O. and Personality Traits	Subject Number								
	28	29	30	31	32	33	34	35	36
T.O.	23	20	18	6.5	34	36	29	21	17
Cautiousness	17	13	9.5	8	29	25.5	25.5	17	3
Ascendancy	19.5	9.5	3	16	5.5	5.5	31.5	17	34
Vigor	27	13	5.5	16.5	5.5	16.5	30	22.5	8.5
Personal Relations	12.5	31.5	20	17	12.5	12.5	35.5	22.5	25
Sociability	12	4.5	7	12	6	12	36	21.5	29.5
Original Thinking	32.5	27	13.5	1	5	8	29.5	5	15
Emotional Stability	16.5	16.5	10.5	7.5	26.5	7.5	24	4.5	28.5
Responsibility	20.5	20.5	14	11.5	20.5	8	32	4.5	16.5

TABLE C-8--Continued

T.O. and Personality Traits	Subject Number								
	37	38	39	40	41	42	43	44	45
T.O.	31	12	4	3	25	15	35	1	10
Cautiousness	20	35.5	20	20	29	13	13	33.5	24
Ascendancy	35	27	29.5	13.5	28	33	29.5	36	4
Vigor	16.5	10.5	25	19	13	32.5	36	35	3
Personal Relations	20	28	24	3.5	22.5	28	17	35.5	33.5
Sociability	26.5	29.5	32.5	21.5	29.5	26.5	29.5	32.5	17.5
Original Thinking	29.5	17.5	25	8	21.5	35.5	21.5	35.5	2
Emotional Stability	30	36	24	2.5	32	16.5	26.5	34	16.5
Responsibility	24	32	8	4.5	34	29.5	36	18	14

TABLE C-8--Continued

T.O. and Personality Traits	Subject Number								
	46	47	48	49	50	51	52	53	54
T.O.	11	19	26	24	13	16	28	2	5
Cautiousness	26	6	9.5	1	35.5	3	29	6	17
Ascendancy	15	23	23	1	19.5	2	9.5	13.5	23
Vigor	27	27	22.5	10.5	30	1.5	22.5	5.5	8.5
Personal Relations	12.5	7	1.5	6	31.5	20	5	33.5	12.5
Sociability	8	17.5	12	3	12	1	12	24.5	17.5
Original Thinking	25	11.5	17.5	13.5	34	10	17.5	5	21.5
Emotional Stability	12.5	2.5	1	28.5	7.5	35	4.5	7.5	21
Responsibility	16.5	14	1.5	29.5	24	32	11.5	8	1.5

TABLE C-9

SPEARMAN RANK CORRELATION[a]--T.O. WITH GORDON TRAITS

Cautiousness

$$r_s = \frac{3,884.5 + 3,855 - 5,523.5}{2\sqrt{(3,884.5)(3,855)}} = .286 \qquad t = .2863\sqrt{\frac{36 - 2}{1 - (.2863)^2}} = 1.742$$

Ascendancy

$$r_s = \frac{3,884.5 + 3,858.5 - 8,819}{2\sqrt{(3,884.5)(3,858.5)}} = -.139 \qquad t = -.139\sqrt{\frac{36 - 2}{1 - (-.139)^2}} = -.819$$

Vigor

$$r_s = \frac{3,884.5 + 3,857 - 7,246}{2\sqrt{(3,884.5)(3,857)}} = .064 \qquad t = .064\sqrt{\frac{36 - 2}{1 - (.064)^2}} = .374$$

Personal Relations

$$r_s = \frac{3,884.3 + 3,850.5 - 10,002}{2\sqrt{(3,884.5)(3,850.5)}} = -.293 \qquad t = -.293\sqrt{\frac{36 - 2}{1 - (-.2931)^2}} = -1.888$$

[a]Spearman Rank Order Correlation T.O. Performance Index ranked 1 to 36 with Gordon Personality Traits ranked 1 to 36.

TABLE C-9--Continued

Sociability

$$r_s = \frac{3,884.5 + 3,840 - 9,797.5}{2\sqrt{(3884.5)(3,840)}} = -.268$$

$$t = -.268\sqrt{\frac{36 - 2}{1 - (-.268)^2}} = -1.625$$

Original Thinking

$$r_s = \frac{3,884.5 + 3,862 - 8,070.5}{2\sqrt{(3,884.5)(3,862)}} = -.042$$

$$t = -.042\sqrt{\frac{36 - 2}{1 - (-.0418)^2}} = -.244$$

Emotional Stability

$$r_s = \frac{3,884.5 + 3,855.5 - 6,462}{2\sqrt{(3,884.5)(3,855.5)}} = .165$$

$$t = .165\sqrt{\frac{36 - 2}{1 - (.165)^2}} = .976$$

Responsibility

$$r_s = \frac{3,884.5 + 3,859.5 - 5,238.5}{2\sqrt{(3,884.5)(3,859.5)}} = .324$$

$$t = .324\sqrt{\frac{36 - 2}{1 - (.324)^2}} = 1.99$$

APPENDIX D

SPEARMAN RANK CORRELATION COEFFICIENT: AQE SCORES WITH PERFORMANCE INDICES

TABLE D-1

AQE SCORES

Aptitude Clusters	Subject Number								
	1	2	3	4	5	6	7	8	9
General	85	95	85	95	95	85	95	85	85
Administrative	30	55	55	55	85	60	80	70	70
Mechanical	65	80	95	55	35	90	95	85	60
Electronics	85	95	95	95	90	85	95	85	95

Aptitude Clusters	Subject Number								
	10	11	12	13	14	15	16	17	18
General	75	95	65	75	75	80	55	95	70
Administrative	65	85	60	20	60	80	50	60	50
Mechanical	50	40	75	85	85	80	90	95	65
Electronics	85	95	95	85	90	80	90	95	80

TABLE D-1--Continued

Aptitude Clusters	Subject Number								
	37	38	39	40	41	42	43	44	45
General	70	40	70	85	95	80	80	65	95
Administrative	50	45	70	95	90	60	70	45	90
Mechanical	90	70	70	55	75	80	90	70	90
Electronics	80	85	95	90	80	90	95	85	95

Aptitude Clusters	Subject Number								
	46	47*	48	49	50	51	52	53	54
General	90	-	90	70	85	95	70	90	70
Administrative	75	-	95	80	90	90	70	60	55
Mechanical	95	-	95	80	85	90	65	90	85
Electronics	95	-	90	85	90	95	70	95	85

*Subject 47 did not have AQE aptitude cluster scores.

TABLE D-2

SPEARMAN RANK ORDERING--API AND AQE SCORES--
INTERMEDIATE LEVEL MAINTENANCE: MORE-THAN-SIX-MONTHS-EXPERIENCE GROUP

API and Aptitude Rankings	Subject Number								
	37	38	39	40	41	42	43	44	45
API[a]	16	6	8	5	14	15	17	2	9
General	13	17	13	7.5	2	9.5	9.5	16	2
Administrative	15	16.5	10	1.5	4.5	12.5	10	16.5	4.5
Mechanical	5	14	14	17	12	10.5	5	14	5
Electronics	15.5	12.5	3.5	8.5	15.5	8.5	3.5	12.5	3.5

API and Aptitude Rankings	Subject Number								
	46	47*	48	49	50	51	52	53	54
API[a]	7	-	12	10	4	13	11	1	3
General	5	-	5	13	7.5	2	13	5	13
Administrative	8	-	1.5	7	4.5	4.5	10	12.5	14
Mechanical	1.5	-	1.5	10.5	8.5	5	16	5	8.5
Electronics	3.5	-	8.5	12.5	8.5	3.5	17	3.5	12.5

[a]Average Performance Index for more-than-six-months group--intermediate level maintenance.

*Subject 47 had no AQE aptitude cluster scores.

TABLE D-3

SPEARMAN RANK CORRELATION--API WITH AQE SCORES--
INTERMEDIATE LEVEL MAINTENANCE: MORE-THAN-SIX-MONTHS GROUP

General

$$r_s = \frac{395 + 408 - 946}{2\sqrt{(395)(408)}} = -.178$$

$$t = -.178\sqrt{\frac{17 - 2}{1 - (-.178)^2}} = -.701$$

Administrative

$$r_s = \frac{408 + 399.5 - 1076.5}{2\sqrt{(399.5)(408)}} = .333$$

$$t = -.333\sqrt{\frac{17 - 2}{1 - (-.333)^2}} = -1.368$$

Mechanical

$$r_s = \frac{408 + 394.5 - 959.5}{2\sqrt{(408)(394.5)}} = -.196$$

$$t = -.196\sqrt{\frac{17 - 2}{1 - (-.333)^2}} = -.773$$

Electronics

$$r_s = \frac{408 + 380 - 716}{2\sqrt{(408)(380)}} = .091$$

$$t = .091\sqrt{\frac{17 - 2}{1 - (.091)^2}} = .355$$

TABLE D-4

SPEARMAN RANK ORDERING--FPTA/LTTA AND AQE SCORES

FPTA, LTTA Ranking of Aptitude Clusters	Subject Number								
	1	2	3	4	5	6	7	8	9
FPTA	34	46	35	19	52	48	13	14	37
LTTA	51	49	19	31	50	35	32	44	27
General	22	5.5	22	5.5	5.5	22	5.5	22	22
Administrative	52	43	43	43	10	37	16.5	27	27
Mechanical	42.5	29	3.5	49.5	53	10.5	3.5	20.5	46.5
Electronics	36.5	9	9	9	15.5	36.5	9	36.5	9

FPTA, LTTA Ranking of Aptitude Clusters	Subject Number								
	10	11	12	13	14	15	16	17	18
FPTA	50	10	17	23	51	33	28	24	41
LTTA	45	43	24	28	37	52	48	46	38
General	38.5	5.5	49.5	38.5	38.5	32.5	52	5.5	44.5
Administrative	32.5	10	37	53	37	16.5	47	37	47
Mechanical	51	52	33	20.5	20.5	29	10.5	3.5	42.5
Electronics	36.5	9	9	36.5	15.5	47.5	15.5	9	47.5

TABLE D-4--Continued

FPTA, LTTA Ranking of Aptitude Clusters	Subject Number								
	19	20	21	22	23	24	25	26	27
FPTA	49	9	11	39	15	22	26	1	12
LTTA	30	36	3	21	1	7	10	40	23
General	44.5	22	32.5	22	32.5	13	22	22	13
Administrative	21.5	10	16.5	27	16.5	43	10	27	37
Mechanical	29	20.5	20.5	3.5	33	46.5	20.5	20.5	46.5
Electronics	47.5	15.5	15.5	9	47.5	15.5	36.5	36.5	47.5

FPTA, LTTA Ranking of Aptitude Clusters	Subject Number								
	28	29	30	31	32	33	34	35	36
FPTA	20	8	25	32	4	3	29	21	47
LTTA	18	47	26	9	4	17	16	20	8
General	32.5	51	22	5.5	22	32.5	44.5	32.5	38.5
Administrative	27	50	16.5	10	32.5	27	2	16.5	16.5
Mechanical	20.5	37.5	20.5	10.5	42.5	46.5	37.5	37.5	20.5
Electronics	15.5	36.5	47.5	9	15.5	36.5	36.5	47.5	9

TABLE D-4--Continued

FPTA, LTTA Ranking of Aptitude Clusters	Subject Number								
	37	38	39	40	41	42	43	44	45
FPTA	5	41	42	36	30	38	53	2	43
LTTA	41	6	15	14	29	39	53	33	12
General	44.5	53	44.5	22	5.5	32.5	32.5	49.5	5.5
Administrative	47	50	27	2	5.5	37	27	50	5.5
Mechanical	10.5	37.5	37.5	49.5	33	29	10.5	37.5	10.5
Electronics	47.5	36.5	9	15.5	47.5	15.5	9	36.5	9

FPTA, LTTA Ranking of Aptitude Clusters	Subject Number								
	46	47*	48	49	50	51	52	53	54
FPTA	30	-	18	45	27	44	16	1	6
LTTA	25	-	11	34	5	42	2	13	22
General	13	-	13	44.5	22	5.5	44.5	13	44.5
Administrative	21.5	-	2	16.5	5.5	5.5	27	37	43
Mechanical	3.5	-	3.5	29	20.5	10.5	42.5	10.5	20.5
Electronics	9	-	15.5	36.5	15.5	9	53	9	36.5

*Subject 47 did not have AQE aptitude cluster scores.

TABLE D-5

SPEARMAN RANK CORRELATION--FPTA WITH AQE SCORES

General

$$r_s = \frac{12,402 + 12,037 - 24,936}{2\sqrt{(12,402)(12,037)}} = -.020$$

$$t = -.020\sqrt{\frac{53 - 2}{1-(-.020)^2}} = -.145$$

Administrative

$$r_s = \frac{12,402 + 12,240 - 28,881.86}{2\sqrt{(12,402)(12,240)}} = -.172$$

$$t = -.172\sqrt{\frac{53 - 2}{1-(-.172)^2}} = -1.247$$

Mechanical

$$r_s = \frac{12,402 + 12,159.5 - 25,346.3}{2\sqrt{(12,402)(12,159.5)}} = -.032$$

$$t = -.032\sqrt{\frac{53 - 2}{1-(-.172)^2}} = -.228$$

Electronics

$$r_s = \frac{12,402 + 11,563.5 - 27,168.5}{2\sqrt{(12,402)(11,563.5)}} = -.2173$$

$$t = -.217\sqrt{\frac{53 - 2}{1-(-.2173)^2}} = -1.589$$

TABLE D-6

SPEARMAN RANK CORRELATION--LTTA WITH AQE SCORES

General

$$r_s = \frac{12{,}402 + 12{,}037 - 25{,}308}{2\sqrt{(12{,}037)(12{,}402)}} = -.036$$

$$t = -.036\sqrt{\frac{53 - 2}{1-(-.036)^2}} = .25412$$

Administrative

$$r_s = \frac{12{,}402 + 12{,}240 - 17{,}824}{2\sqrt{(12{,}402)(12{,}240)}} = .277$$

$$t = .277\sqrt{\frac{53 - 2}{1 - (.277)^2}} = 2.056^*$$

Mechanical

$$r_s = \frac{12{,}402 + 12{,}159.5 - 24{,}606.25}{2\sqrt{(12{,}402)(12{,}159.5)}} = -.002$$

$$t = -.002\sqrt{\frac{53 - 2}{1 - (.002)^2}} = -.013$$

Electronics

$$r_s = \frac{12{,}402 + 11{,}563.5 - 24{,}027.75}{2\sqrt{(12{,}402)(11{,}563.5)}} = -.003$$

$$t = -.003\sqrt{\frac{53 - 2}{1 - (-.003)^2}} = -.019$$

*Significant at $\alpha = 5$.

TABLE D-7

SPEARMAN RANK ORDERING--T.O. AND AQE TEST SCORES

T.O. Ranking of Aptitude Clusters	Subject Number[a]								
	19	20	21	22	23	24	25	26	27
T.O.[b]	26	32	8	21	8	14	6.5	29	31
General	28.5	13.5	21	13.5	21	7	13.5	13.5	7
Administrative	17.5	9	13.5	22	13.5	30.5	9	22	28
Mechanical	20	14	14	2	22.5	32	14	14	32
Electronics	31	14	14	5	31	14	23	23	31

T.O. Ranking of Aptitude Clusters	Subject Number[a]								
	28	29	30	31	32	33	34	35	36
T.O.[b]	22	19	18	6.5	33	35	28	20	17
General	21	34	13.5	2.5	13.5	21	28.5	21	25
Administrative	22	34	13.5	9	26	22	2	13.5	13.5
Mechanical	14	26	14	6.5	27.5	32	26	26	14
Electronics	14	23	31	5	14	23	23	31	5

[a]Zero experience group was not tested with T.O.

[b]T.O. performance index ranked 1 to 35.

TABLE D-7--Continued

T.O. Ranking of Aptitude Clusters	Subject Number[a]								
	37	38	39	40	41	42	43	44	45
T.O.[b]	30	11	4	3	24	15	34	1	10
General	28.5	35	28.5	13.5	2.5	21	21	33	2.5
Administrative	32	34	22	2	4.5	28	22	34	4.5
Mechanical	6.5	26	26	34	22.5	20	6.5	26	6.5
Electronics	31	23	5	14	31	14	5	27	5

T.O. Ranking of Aptitude Clusters	Subject Number[a]								
	46	47*	48	49	50	51	52	53	54
T.O.[b]	11	-	25	23	13	16	27	2	5
General	7	-	7	28.5	13.5	2.5	28.5	7	28.5
Administrative	17.5	-	2	13.5	4.5	4.5	22	28	30.5
Mechanical	2	-	2	20	14	6.5	27.5	6.5	14
Electronics	5	-	14	27	14	5	35	5	23

[a]Zero experience group was not tested with T.O.

[b]T.O. performance index ranked 1 to 35.

*Subject 47 did not have AQE aptitude cluster scores.

TABLE D-8

SPEARMAN RANK CORRELATION--T.O. WITH AQE SCORES

General

$$r_s = \frac{2457.5 + 3569.5 - 6729.25}{2\sqrt{(3467.5)(3569.5)}} = .044$$

$$t = .044\sqrt{\frac{35 - 2}{1 - (.044)^2}} = .252$$

Administrative

$$r_s = \frac{3510.5 + 3569.5 - 6643}{2\sqrt{(3510.5)(3569.5)}} = .062$$

$$t = .062\sqrt{\frac{35 - 2}{1 - (.062)^2}} = .355$$

Mechanical

$$r_s = \frac{3475.5 + 3569.5 - 6215.75}{2\sqrt{(3475.5)(3569.5)}} = .118$$

$$t = .118\sqrt{\frac{35 - 2}{1 - (.118)^2}} = .681$$

Electronics

$$r_s = \frac{3569.5 + 3362 - 5263.75}{2\sqrt{(3569.5)(3362)}} = .241$$

$$t = .241\sqrt{\frac{35 - 2}{1 - (.241)^2}} = 1.425$$

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